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Effects of Caging Juvenile Predators on Benthic Infaunal Populations at Experimental Open Bay Disposal Areas in Galveston Bay, Texas

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Thomas Minello and Ronald Wooten

National Marine Fisheries Service

Southeast Fisheries Center

Galveston Laboratory

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Abstract

Predator enclosure experiments were conducted in spring and fall of 1992 at experimental (with dredged material) and control plots in Galveston Bay in order to examine the trophic relationships between benthic infaunal prey and macrobenthic and nektonic consumers. We caged juvenile brown shrimp *Penaeus aztecus* (24-35 mm, TL), sciaenid fish *Micropogonias undulatus* (43-63 mm, TL), white shrimp *Penaeus setiferus* (31-40 mm, TL) and blue crabs *Callinectes sapidus* (12-17 mm, CW) *in situ* at the plots for a period of 3-5 days. Survival of crustacean predators in cages was high, but none of the experimental fish survived. The impact of enclosed predators on the benthic infauna was determined by comparing infaunal density and biomass in treatment cages with control cages (no predators). Predator growth was also measured. There was no detectable predation by experimental predators on annelids, the most abundant infaunal group. Previous research has shown that annelids (including species identified from the plots) are commonly eaten and are valuable prey items in the diets of these predators. Annelid densities at the plots, however, may have been too low to allow efficient exploitation by predators. Blue crabs did not appear to feed on any infauna. Positive blue crab growth was measured, however, at control plots. Growth rates of this predator were significantly reduced at experimental plots with dredged material. Juvenile brown shrimp and white shrimp fed on amphipods and small molluscs. Prey reduction was greater at control plots than at experimental plots, suggesting that dredged material sediments provided fewer prey. Shrimp growth rates, however, were not significantly different among the plots.

Introduction

This benthic caging study was part of a larger project designed to examine biological recovery of submerged, new work, dredged material along the Houston Ship Channel in Galveston Bay, Texas. Two study areas were examined, one in the upper bay and one in the lower bay. Within each of these areas, three square 9.3-hectare plots (two control and one experimental) were identified, and dredged material was placed at the experimental plots in the winter and early spring of 1992. A major component of the larger project involved sampling of benthic infauna at the plots three times per year, to compare infaunal populations between the control and experimental plots and to track the recovery of these populations following the disposal operation. The sampling of benthic infaunal populations (conducted by U.S. Army's Waterways Experiment Station) was conducted in part under the assumption that the quality of the habitat for fish, shrimp and crabs is related to the density of these prey organisms. Infaunal densities, however, provide only limited information on benthic productivity, availability of benthic animals to predators, and the trophic relationships between benthic infaunal prey and macrobenthic and nektonic consumers. This benthic caging study was designed to examine utilization of infaunal populations by common benthic predators and relative trophic value of sediments at experimental and control plots.

In order to provide information on the trophic relationships between infaunal populations and their predators, we enclosed predators in cages over a section of bay bottom and measured the response of the infauna to predation pressure. This technique can provide data on selectivity in feeding patterns of predators and on the contribution of benthic populations to the bay's trophic web. Enclosed predators included juvenile shrimp, crabs, and fishes, and replicate cages were placed at the two experimental and four control plots for a short period (3-5 days) during the spring and fall. Following this experimental period, infaunal populations in the predator cages were compared with populations in control cages and in uncaged control cores. We also examined predator growth in the cages, because growth can be used as an indicator of the relative value of bay bottom in providing food and in supporting fishery productivity.

Methods

The caging experiments were conducted in the spring (May 8-18) and fall (August 31 to September 5) of 1992 at six plots in Galveston Bay. The plots were arranged into an upper bay and a lower bay group, each group with two control plots and an experimental plot (Figure 1). Each plot was approximately 305 m by 305 m square, and all plots were separated by at least 1.6 km. At the experimental plots, a layer of new-work dredge material from the Houston Ship Channel was placed over the plot to a depth of approximately 0.6 m between January and March 1992. Control plots were not modified.

Cages were constructed from 15-cm long sections of PVC pipe with a 20.3-cm inner diameter. A mesh bag made of 2-mm Nitex was attached to the section of pipe with a hose clamp. This mesh extended approximately 15 cm above the pipe, and the entire cage vaguely resembled a Chef's hat. SCUBA divers were used to deploy and retrieve the cages. The PVC pipe section of the cage was pushed into the substratum until only the Nitex mesh was protruding above the bottom. This design was adopted to minimize loss of cages to trawling.

At each of the six plots we placed five clusters of cages. Each cluster was marked with a bamboo pole and a buoy attached to a screw-anchor placed in the sediment. One cluster was located in the center of the plot, and the other four clusters were placed around this central cluster at a distance of at least 30 m. A cluster consisted of two cages with predators (each with a different species) and an empty control cage. Immediately before deployment, cages with predators were inverted in a bucket, and the experimental predator was measured for total length (TL) or carapace width (CW) and placed into the top portion of the cage. A clamp was used to seal the animal into a bag made from this mesh portion of the cage. Divers then carried the cage to the bay bottom, pushed the cage into the substratum, and released the predator.

The predatory species used in experiments were selected after trawling near the plots before the experiments. The experimental predators used were identified from these trawls as abundant in the area. Predators were then collected with trawls and seines the day before the cages were deployed and held in large fiberglass tanks with aeration but no food. In the spring, the experimental predators included juvenile brown shrimp *Penaeus aztecus* (24-35 mm, TL) and juvenile Atlantic croaker *Micropogonias undulatus* (43-63 mm, TL), a sciaenid fish. In the fall, the predators were juvenile white shrimp *Penaeus setiferus* (31-40 mm, TL) and blue crabs *Callinectes sapidus* (12-17 mm, CW).

After an experimental period of 3-5 days the predator and control cages were retrieved by divers. An uncaged control was also collected at this time for each cluster of cages. This control core was collected by taking an empty cage to the bottom near the experimental cages, pushing it into the substratum, and immediately retrieving the cage. Divers removed each cage from the substratum with its associated sediment and immediately placed the cage into a PVC cap to prevent sediment loss. The cage and cap were then placed into a 200-μ mesh bag and brought to the surface. Once onboard, predators were removed and measured. Three 2.6-cm diameter cores (5.3 cm^2 area, 5 cm deep) were then removed from the cage sediment. One of these cores was retained for grain-size analysis. The upper 3 cm of the other two cores were placed in a ziplock bag and preserved in formalin for possible meiofauna analysis. The remaining upper 5 cm of the cage sediment (307.7 cm^2 area of bottom) along with the contents of the mesh bag used for cage retrieval were sieved through a 500-μ mesh and preserved in 10% formalin. The experimental predator was preserved with the contents from the sieve.

For each cage cluster, bottom temperature, salinity, turbidity and dissolved oxygen were measured both when the cages were deployed and when they were retrieved. Temperature and dissolved oxygen were measured with a YSI Model 51B meter. Salinity and turbidity were measured in the laboratory from a bottom water sample. Salinity was measured with a refractometer and turbidity with an HF Instruments nephelometer (Model DRT 100B). In addition, two DataSondes were placed near the bottom on structures located near both the upper and lower plot groups (Figure 1). Each DataSonde unit measured temperature, salinity, and dissolved oxygen every 0.5 hr throughout the experimental period.

Benthic infauna retained on the 500-μ sieve (excluding experimental predators) were identified to the lowest feasible taxonomic level and counted. The dry weight of major animal groups was also determined. The effects of cages on sedimentation were examined by conducting grain size analyses on samples from control cages and uncaged bottom during spring according to the procedures of Folk (1980). The sediment samples collected for meiofauna analysis (total bottom area of 10.6 cm^2 for each cage) were cataloged and stored for possible future analysis.

Abundance and biomass data were analyzed with a two-way ANOVA using Type III sums of squares to adjust for unbalanced cell sizes. Main effects of Plot (n=6) and cage Treatment (n=3 in spring, n=4 in fall) were included in the model. Consistent positive linear relationships between cell means and standard deviations were apparent for both abundance and biomass observations, and a logarithmic (+1) transformation was used in the ANOVAs to correct this heteroscedasticity. A significant interaction between the main effects of Plot and Treatment in the ANOVA was interpreted as an indication that the caging treatments did not have the same effect at each plot. *A priori* contrasts were also constructed from within the Plot effect to compare means in experimental plots with means in control plots, from within the Treatment effect to compare means from predator cages with means from control cages, and from within the interaction term to compare predator cages with control cages separately for the experimental and control plots.

Polychaetes that we believed were available to the enclosed predators were also analyzed separately as a group. The species included in this group were selected on the basis of their reported vertical distributions in the substratum, feeding modes, and previous experimental predation studies conducted at the Galveston NMFS laboratory. The number of polychaete species identified in a core was also analyzed in a two-way ANOVA to examine possible predation effects on species richness. This variable was not transformed.

In addition to the above primary analysis, a secondary analysis of predation effects was conducted by creating a new variable representing infauna removed by enclosed predators. The cage results were paired by clusters in this analysis, and the difference was calculated between the infaunal abundance or biomass in the control cage and in the cage with a predator. A one-way ANOVA was then calculated to compare Plots using this amount of infauna lost to predators (LP) as the observation. Contrasts were also used in this analysis to compare control and experimental plots. The results of this secondary analysis were generally similar to those of the primary two-way ANOVAs. These secondary results, therefore, are only reported for selected groups of animals or in situations where the secondary analysis differs substantially from other analyses.

A one-way ANOVA comparing plots was also calculated from growth data collected during the experiments. Daily growth (24 hrs) was determined by the difference in total length or carapace width of experimental predators between the beginning and end of the experiment, adjusted for the experimental duration measured in hours. A regression of this daily growth with the difference variable measured above (LP) was also examined to look for a relationship between growth and removal of benthic infauna in experimental cages.

Results

Spring Experiment

Five replicate cages were initially deployed at each plot for each of the experimental treatments (brown shrimp, Atlantic croaker, control cage), but upon retrieval it was apparent that the experimental fish had not survived in the cages (30 enclosed, 0 recovered alive). Survival of brown shrimp in this initial deployment of cages was 78% (21 of 27), and where possible additional shrimp cages with control cages were deployed to help balance the analysis. These additional cages also helped to replace cages lost, tipped open, or contaminated with non-experimental predators. Table 1 provides a summary of the number of cages successfully recovered for each experimental treatment.

Bottom water temperature measured at the time cages were deployed and retrieved was similar among the plots as was dissolved oxygen (Figure 2). Salinities were highest at the lower bay plots and lowest at the upper bay plots. Bottom water turbidity was highest at plots D and E, located closest to the center of the bay. None of these water parameters appeared to be significantly different between experimental plots and control plots. Water depth, however, was significantly shallower at the experimental plots, due to the deposition of dredged material. The DataSonde records clearly show the difference in bottom water salinity between the upper and lower bay areas (Figure 3). Water salinity in the lower bay was also characterized by large short-term fluctuations that are presumably related to tidal movement of water in and out of the system.

Grain size analyses indicated that plots in the lower bay contained more sand than those in the upper bay (Figure 4), and two-way ANOVAs on the percentage of sand and the percentage of clay had significant Plot effects (df = 5, 36; Ps = <0.001). The percentage of sand and clay within control cages, however, did not appear to be significantly different compared with non-caged cores, and both this Treatment effect and the interaction term in the ANOVAs were not significant (all Ps > .19).

The infauna identified from the cages and controls in the spring was dominated by polychaete annelids (61% of total infauna, Table 2). *Mediomastus* spp. was most abundant making up 39.0% of the annelids; other abundant species included *Streblospio benedicti* (23.7%) and *Polydora socialis* (9.6%). Crustaceans (mostly amphipods and small decapods) made up 10.4% of the infauna by number, and molluscs (9.5%) and the hemichordate *Balanoglossus* spp. (12.6%) were also abundant. By dry weight, molluscs (with shells) made up 45% of the infauna, and annelids and crustaceans contributed 26% and 24%, respectively.

Total infaunal abundance was greatest at Plot A while biomass was high at both Plot A and Plot B (Figure 5). The high biomass at Plot B was mainly due to molluscs with their associated shells. The ANOVA showed a significant Plot effect, but there did not appear to be any significant effect of the experimental caging Treatment for either total infaunal abundance or biomass (Table 3). The interaction term and the contrasts comparing the cages with shrimp to control cages were also not significant in the ANOVA.

Annelids were the most abundant group within the infauna, and annelid abundance and biomass varied among the plots (Figure 6, Table 3). The mean abundance of annelids in the experimental plots was significantly lower than in the four control plots (Contrast $P < 0.001$), but a similar contrast for annelid biomass was not significant ($P = 0.79$). When the average weight per annelid was analyzed in a similar ANOVA, there was a significant Plot effect (5, 67 df, $P < 0.001$), and the mean weight of individuals was significantly greater at experimental Plots (1.6

mg/individual) compared with control plots (0.40 mg/individual; Contrast $P < 0.001$). Predation by brown shrimp in the cages did not significantly affect annelid numbers, biomass (Table 3), or size (ANOVA; 2, 67 df; $P = 0.14$), and the cage Treatment did not interact with Plots. Similar results were apparent when the loss to predation was analyzed for shrimp cages; there was no significant Plot effect for this variable based on either abundance or biomass (one-way ANOVAs; df = 5, 20; Ps > 0.20).

The polychaete species available to shrimp predators are identified in Table 2. On the basis of this distinction, only 51% of the polychaetes present in the samples were available to the predators. Compared with total annelids, the distribution of available polychaetes appeared more even among the plots except for high densities at Plot F, the upper bay experimental plot (Figure 7). This distribution caused a significant Plot effect in the ANOVA (Table 3). However, densities at the experimental plot in the lower bay were not elevated, and the contrast testing whether abundance was different between the experimental and control plots was not significant ($P = 0.45$). The main effect of the experimental Treatment in the ANOVA approached significance ($P = 0.080$), but the contrast between mean abundance in control cages versus shrimp cages was not significant ($P = 0.15$). Species richness in the samples was greatest at Plot A in the lower bay (Figure 7), and the Plot effect in the ANOVA was significant (Table 3). The contrast within this Plot effect indicated that the mean number of polychaete species in a sample was significantly lower at the experimental plots ($P < 0.001$). The lack of a Treatment effect in the ANOVA, however, indicated that predation in the cages did not appear to affect species richness.

Within the annelids, *Mediomastus* spp. and *Streblospio benedicti* were the most abundant polychaetes, and *Mediomastus* was conspicuous by an almost total absence from the experimental plots (Figure 8). The ANOVA Plot effect was highly significant for both of these polychaetes (Table 3), and the contrasts within this effect indicated that densities were significantly lower in the experimental plots compared with the control plots (Ps < 0.001). The cage Treatment and interaction terms in the ANOVAs, however, were not significant (Table 3), indicating that brown shrimp did not reduce densities of these animals in the cages. Other abundant polychaetes included

Polydora socialis and *Paraprionospio pinnata*, and these species were patchily distributed across plots (Figure 9). Both *Polydora socialis* and its congener *P. cornuta* were found almost exclusively at experimental Plot F in the upper bay.

Crustaceans identified from the infauna were mainly amphipods and small decapods (Table 2). There were significant differences in the abundance of this group among plots (Figure 10, Table 3), but experimental plots were not different from control plots (Contrast $P = 0.40$). The biomass of crustaceans also varied among plots, and mean biomass values at experimental plots were significantly larger than at control plots (Contrast $P < 0.001$). This discrepancy between the abundance and biomass patterns for crustaceans suggested that crustaceans were larger at experimental plots, and indeed the average dry weight per crustacean at control plots was 0.9 mg compared with 33.2 mg at experimental plots. Differences in biomass of crustaceans were mainly influenced by the presence of small decapods. The abundance of crustaceans as a group also varied significantly with respect to the cage Treatment in the ANOVA. Mean values were not significantly different between the control cages and shrimp cages (Contrast $P = 0.18$), but these means were significantly larger than those of the uncaged cores (Games-Howell multiple range test on main effect of Treatment, $\alpha = 0.05$). Similar to crustaceans as a group, amphipod abundance varied in relation to both the Plot effect and the cage Treatment effect (Table 3). Plot means for amphipod abundance in the uncaged controls were lower than in both cage treatments except at Plot G (Figure 11), causing a significant interaction in the ANOVA model; in fact at the lower bay plots, amphipods were absent outside of cages. Contrasts within the interaction term, however, indicated that there were no significant differences in amphipod abundance between control cages and shrimp cages at either the control plots or experimental plots (Table 3). On the basis of main effects in the ANOVA, amphipod abundance was significantly higher at experimental plots compared with control plots (Contrast $P = 0.007$), and there was an indication of a predation effect. The overall mean density of amphipods in control cages was 2.7 compared with a mean value of 1.4 in the predator cages (Contrast $P = 0.057$).

The density and biomass of molluscs also varied significantly among plots (Figure 12, Table 3), and values in experimental plots were greater than in control plots (Contrast $Ps < 0.015$). Overall, mollusc abundance was significantly lower in cages with shrimp predators compared with control cages (Contrast $P = 0.023$). The contrasts within the interaction term suggested that the cage effect occurred at the control plots and not at the experimental plots (Table 3), but the overall interaction term was not significant in the ANOVA. When the difference variable (LP) between control cages and predation cages was examined in a one-way ANOVA, there was no significant Plot effect ($P=0.99$). Apparently, predation by shrimp occurred on molluscs at all of the plots, and there was no difference in this effect between control and experimental plots. The dominant mollusk in the samples was the dwarf surf clam *Mulinia lateralis*. This species was most abundant at the experimental plots, and was completely absent at the lower control plots (Figure 13). There was some indication of predation effects at the experimental plots, but the ANOVA results may be unreliable due to the large number of zeros in the data set.

The hemichordate *Balanoglossus* was present in relatively large numbers at Plot A in the lower bay but not found at any of the other plots (Figure 13). Brown shrimp did not appear to prey upon these acorn worms, and there was no obvious effect of the cage treatment.

Growth data were obtained from 24 brown shrimp enclosed at the six plots (Figure 14). Mean initial total length for shrimp was 31.9 mm (SE = 0.99). Despite the short experimental duration, (mean = 91 hrs, SE = 3.1) the mean daily growth rate (per 24 hrs) was 1.2 mm (SE = 0.14). Growth appeared lowest at experimental Plot B, but a one-way ANOVA indicated that there was no significant difference among the plots in daily shrimp growth (5,18 df, $P = 0.22$). Linear regressions of brown shrimp growth versus loss of prey from cages (LP variable) were not significant for abundance of annelids, crustaceans, or molluscs or for biomass of annelids or molluscs ($Ps > 0.26$, $n = 24$). There was a significant ($P = 0.010$) positive linear relationship between growth and the difference in biomass of crustaceans between the control and predator cages ($R^2 = 26\%$). Low shrimp growth, however, occurred mainly where predator cages had higher biomass than control cages (negative LP), and this relationship may have been due to competition for food with other small decapods in predator cages.

Fall Experiment

Survival of the experimental predators was better in the fall than in the spring; 25 of 27 white shrimp (92%) and 26 of 27 blue crabs (96%) survived. Some observations were lost due to missing or tipped cages or deleted because of contamination with other potential predators (Table 1).

Bottom water temperatures were higher in the fall than in the spring as were salinities (Figure 15), but a similar pattern of reduced salinity at the upper bay plots was apparent. Water turbidity was much lower in the fall compared with the spring, and there were no major differences in turbidity among plots. The DataSonde record in the upper bay revealed an abrupt drop in bottom water temperature around September 4 (Figure 16). Temperatures averaged 28.3 °C from August 31 to September 4 and 24.4 °C from September 5 through 9. The DataSonde record in the lower bay terminated after September 3 due to an equipment failure. The bottom water salinity fluctuations seen in the spring were also apparent in this shorter fall record.

Overall, the infauna were again dominated in number by the annelids (62%, Table 4). Within the annelids the polychaete *Mediomastus* spp. was again most abundant making up 38% of this group, followed by *Glycinde solitaria* (13.3%), *Paraprionospio pinnata* (12.7%), and *Parandalia Sp. A* (6.1%). Molluscs were also abundant making up 19.8% of the infauna followed by crustaceans (11.3%) and an unidentified rhynchocoel (6.3%). In biomass, molluscs made up 62.5% of the infauna, followed by annelids (20.3%) and crustaceans (14.2%).

Total infaunal abundance at the different plots was more evenly distributed in the fall than in the spring, and a steady decline in numbers was apparent from the lower bay to the upper bay (Figure 17). As in the spring, fall biomass of infauna was highest at Plot B, mainly due to an abundance of molluscs at this experimental plot. There was a significant Plot effect in the ANOVAs for both biomass and abundance (Table 5), but the contrast comparing means at experimental plots versus control plots was only significant for biomass ($P < 0.001$) and not for abundance ($P = 0.52$). This difference in results suggested that the mean size of infaunal organisms was greater at experimental plots, and a contrast of experimental and control plots within the Plot effect of an ANOVA on weight per individual was significant ($P = 0.031$). Predation by enclosed predators did not significantly affect abundance or biomass of total infauna (Table 5).

Annelids as a group were significantly more abundant at the control plots compared with the experimental plots (Figure18; Contrast within ANOVA Plot effect, $P < 0.001$), but biomass did not vary significantly among the plots. An ANOVA on annelid size indicated a significant Plot effect (5, 77 df; $P = 0.009$), and the mean size of annelids at experimental plots (3.6 mg dry wt per individual) was significantly greater than the mean size at control plots (1.2 mg per individual; Contrast $P < 0.001$). The cage Treatment did not significantly affect annelid abundance (Table 5). Although there was a significant cage Treatment effect for annelid biomass, the biomass in control cages was not significantly different from biomass in cages with crabs or shrimp (Contrast Ps > 0.27). The analyses of loss to predation from predator cages (control cage - shrimp or crab cage) also indicated there were no significant predation effects by white shrimp or blue crabs on annelid abundance or biomass; the Plot effects in the one-way ANOVAs were not significant for these loss variables (df = 5, 20; Ps > 0.11).

Polychaetes available to predators only made up 30% of the total polychaetes in the fall (Table 4). Similar to total annelids, there were significant differences among the plots for this group (Figure 19, Table 5). In contrast to total annelids, however, the mean number of polychaetes available was greater at the experimental plots compared with the control plots (Contrast $P = 0.054$). The enclosed predators did not appear to affect the number of available polychaetes in the cages (Table 5). The number of polychaete species identified in samples declined steadily from the lower bay to the upper bay (Figure 19). There were significant differences among plots (Table 5), but in contrast to the spring results, the experimental plots were not significantly different from the control plots (Contrast $P = 0.82$). Similar to the results from the spring, the enclosed predators did not appear to affect species richness.

Mediomastus spp. had apparently recruited to some extent into the experimental plots (Figure 20) compared with the spring distributions, but densities were still significantly lower at experimental plots compared with control plots (Contrast $P < 0.001$). *Glycinde solitaria* and *Parandalia Sp. A* were rarely found in the spring samples, but in the fall these species were relatively abundant at the plots (Figures 20 and 21). *Paraprionospio pinnata* was mainly abundant in the lower bay (Figure 21). Numbers of both *G. solitaria* and *P. pinnata* varied among plots (Table 5), and values were significantly lower in experimental plots compared with control plots (Contrast $P = 0.001$). There were no significant Treatment effects for any of the polychaetes examined (Table 5), indicating that predation by white shrimp and blue crabs did not affect their abundances.

The abundance of total crustaceans and decapods varied significantly among the plots (Table 5, Figures 22 and 23), and the abundance of decapods was significantly greater at the experimental plots compared with the control plots (Contrast $P < 0.001$). Although the main effect of the caging Treatment was significant for crustaceans as a group and for amphipods, this was mainly due to an increase in abundance of these prey in all caged treatments compared with the uncaged controls (Table 4). There were no apparent reductions in crustaceans by enclosed crab predators (Table 5). Enclosed shrimp predators, however, significantly reduced both overall crustacean prey and amphipods at control plots (Table 5). This predation effect was not present at the experimental plots. In the analyses of prey lost to shrimp predators (LP), the overall Plot effect was not significant (one-way ANOVAs, $Ps > 0.16$), but contrasts within the ANOVA also indicated that shrimp predators had removed more crustaceans ($P = 0.042$) and amphipods ($P = 0.069$) from control plots than from experimental plots.

The abundance and biomass of molluscs in the fall varied significantly among plots (Figure 24, Table 5), and values were greater at experimental plots compared with control plots (Contrast $Ps < 0.002$). Mollusc abundance was affected by the cage Treatment, and overall, cages with white shrimp predators had significantly fewer molluscs than cages without predators (Contrast $P = 0.019$). The caged blue crabs did not appear to affect the abundance of molluscs. Although the interaction term in the ANOVA was not significant, the contrasts within this term suggested that the apparent predation effect by shrimp occurred at control plots but not at experimental plots (Figure 24, Table 5). *Mulinia lateralis* made up 63% of the molluscs in the samples, and the predation effect by shrimp on this species paralleled that of total molluscs (Figure 25, Table 5).

An unidentified rhynchocoel (nemertean or proboscis worm) was abundant in the samples of the lower bay (Figure 25). There was a significant Plot effect in the ANOVA for this species (Table 5), and there were fewer of these organisms at the experimental plots compared with the control plots (Contrast $P = 0.001$). Predation by white shrimp or blue crabs, however, did not appear to affect rhynchocoel abundance.

Growth could be measured for 20 white shrimp enclosed in cages (initial TL = 35 mm, SE = 0.50), and the overall mean daily growth rate was 0.3 mm per 24 hr (SE = 0.07). There was no significant difference among the plots in shrimp growth (Figure 26; one-way ANOVA; 5, 14 df; $P = 0.41$). There were no significant regressions between white shrimp growth and loss of major infaunal groups in the shrimp predator cages, although the regression approached significance for biomass of molluscs ($P = 0.063$). The mean daily growth rate for blue crabs (initial CW = 14 mm, SE 0.31) in cages was 0.4 mm (SE = 0.10, n = 25). Mean growth rates were lowest at the two experimental plots (Figure 27), and although the overall Plot effect in the ANOVA was not significant (5, 19 df; $P = 0.13$), a contrast comparing growth at experimental plots and control plots was significant ($P = 0.021$). Regressions between blue crab growth and loss of infaunal groups from crab cages were not significant ($Ps > 0.072$).

Discussion

The objectives of this study were primarily to measure infaunal removal from the sediment by common estuarine predators, and to determine whether the contribution of infauna to the diet of these predators differed among the control and experimental plots. Secondarily, we hoped to obtain measures of predator growth at the different plots for use in estimating relative habitat value among the plots. During the course of our study, however, we also obtained information on abundance and biomass patterns for infaunal populations at the experimental and control plots during the spring and fall of 1992. These data should be useful for comparison with the more extensive benthic infaunal sampling conducted concurrently by the U.S. Army, Corps of Engineers, Waterways Experiment Station.

Annelids were the most abundant infaunal group, and annelid abundance was generally low at experimental plots in relation to control plots. However, the biomass of annelids and abundances of polychaetes available to predators (Tables 2 and 4), were either similar among plots or greater in the experimental plots (Table 6). The dominant annelids found in our study were the polychaetes *Mediomastus* spp., *Streblospio benedicti*, *Polydora socialis*, *Paraprionospio pinnata*, *Glycinde solitaria* and *Parandalia Sp. A*. *Mediomastus* is in the family Capitellidae, and capitellids are generally non-selective, motile, subsurface deposit feeders (Fauchald and Jumars 1979, Gaston et al. 1988). Gaston (1987) found organic detritus to be the main food component for *Mediomastus californiensis* in a gut study analysis of polychaetes from the Middle Atlantic Bight. Feeding in *Mediomastus* is accomplished through eversion of a papillose, sac-like proboscis. *Mediomastus* exhibits a preference for mud or sandy mud habitats, and is found in a variety of salinities. *Mediomastus ambiseta* , a common species in this genus, is free spawning and produces planktonic larvae (Wilson, 1991). Although the majority of *Mediomastus* were not identified to species, a large proportion of these polychaetes were likely *M. ambiseta* or another abundant species in Gulf coast estuaries *M. californiensis* (Gaston et al. 1988). This genus was considered generally unavailable to benthic feeding predators because it is a subsurface deposit feeder (Gaston et al. 1988).

The spionids (*Streblospio, Polydora,* and *Paraprionospio)* are highly motile, opportunistic surface deposit and/or suspension feeders, known to feed on sediment particles and planktonic and meiobenthic organisms (Grassle and Grassle 1974, Fauchald and Jumars 1979, Dauer et al. 1981). These near-surface dwellers made up the largest group of annelids considered available to predators. *Streblospio benedicti* is widely distributed over all sediment types but is considered a mud dwelling species, and is common in lower salinity and euryhaline environments. Colonization and increased growth and reproduction have been observed in stressed populations or those in organically enriched sediments (Grassle and Grassle 1974, Levin 1986). Sexes are separate in *S. benedicti*, and eggs are brooded in a brood pouch for 4-5 days before the larvae are released into the plankton (Levin et al. 1987, Wilson 1991). Adults attain lengths to 9 mm (Levin 1987). Another abundant spionid in our samples, *Polydora socialis,* inhabits U-shaped tubes that are usually constructed in a sandy silt substrate, and this species is generally found under euryhaline and polyhaline conditions (Dauer et al. 1981, Johnson 1984). A congener, *P. ligni* has been described as an early colonizer of estuarine fouling communities (Dauer et al. 1981), and is found as a dominant species in silty-clay sediments. The sexes are separate in *P. socialis* , and egg capsules are brooded within the females burrow (Wilson 1991), but larvae are planktonic. Adults of this species reach lengths from 15 to 55 mm (Johnson 1984). *Paraprionospio pinnata* was also abundant, and this species is highly motile, and is known to colonize disturbed habitats (Dauer et al. 1981, Van Dolah et al. 1984). *P. pinnata* is found in a variety of sediment types and occurs in polyhaline conditions. Sexes are separate with probable free spawning, and larvae are probably planktonic. Adult body length may reach 48 mm (Johnson 1984).

Other abundant species included the goniadid *Glycinde solitaria.* This species is a motile carnivore, utilizing an eversible pharynx armed with small jaws in prey capture (Gilbert 1984). Goniadids are known from a variety of water depths and substrates, but burrowing activity has not been described. Within the family, spawning usually occurs at the water's surface after which the adults die (Gilbert 1984). Although no information was found on *G. solitaria* larvae, congeners are free spawning with planktonic larvae (Wilson 1991). *G. solitaria* body length has been reported from 9.5 mm to 35 mm (Gilbert 1984). *Parandalia Sp. A* was also present and, along with other members of the family Pilargidae, is considered a carnivore or an omnivore based on morphological characteristics (Wolf 1984). Pilargids are motile, creeping on the surface of the substratum, and have not been observed building tubes. As far as is known, sexes are separate, and planktonic larvae have been collected by Pettibone (1982, cited in Wolf 1984). Lengths have been reported from 20+mm (Wolf 1984).

Predation by the enclosed shrimp and crab predators in our experiments did not affect annelid abundance (Table 6). The predators used in this study, however, are known to feed upon annelids (including species such as *Streblospio benedicti*) when prey densities are high. Similar caging experiments using juvenile brown shrimp and white shrimp as predators feeding on intertidal sediments have shown dramatic reductions in annelid abundance (Minello and Zimmerman 1991). These data suggest, therefore, that annelid densities at the plots were too low to allow exploitation by these benthic predators. Combined with the lack of differences among the plots in the abundances of available annelids, these results indicate that the disposal of dredge material at the two experimental plots did not reduce the value of the sediments in providing annelids to predators.

Crustaceans in the infauna were mainly amphipods and small decapods. Crustacean abundance and biomass was generally similar among the plots or higher at the experimental plots compared with the control plots. Enclosed brown shrimp in the spring experiment fed on amphipods and significantly reduced their abundance; this effect was similar among plots. In the fall, white shrimp also reduced abundances of amphipods, but this predation effect only occurred at the control plots (Table 7). These data on white shrimp suggest that amphipods at the experimental plots were less available to predators. The importance of this conclusion is questionable, however, because overall amphipod abundances were low and removal by predators was minimal. In addition, possible cage effects confound the interpretation of predation results on amphipods. Amphipods may have been attracted to cages because densities in all cage treatments (predator and controls) were significantly higher than in uncaged controls.

Small molluscs were also common within the infauna, and both the abundance and biomass of this group was higher at experimental plots compared with control plots (Table 6). The dominant mollusc was the dwarf surf clam *Mulinia lateralis*. This small (adult length is 8-12 mm) filter-feeding bivalve is euryhaline and associated with clay sediments (Andrews 1971). Molluscs were preyed upon by both brown shrimp and white shrimp in the experiments, but the number eaten at the control plots was greater than at the experimental plots (Table 7). This difference occurred despite the elevated abundances at experimental plots and indicated that molluscs at experimental plots were less accessible to shrimp predators than at control plots.

Growth of enclosed predators was estimated by measuring changes in total length or carapace width over the experimental period (approximately 4 days). Although small blue crabs did not reduce the abundances or biomass of any infaunal organisms examined, growth rates were 0.4 mm (CW) per day. The initial size of these crabs was about 14 mm (CW), and they may have been feeding on meiofauna in the cages rather than macrofauna. Crab growth rates at experimental plots were significantly lower than at control plots. Thus, if we use crab growth as an indicator, the benthic habitat value was lower at the experimental plots than at the control plots. Growth of brown shrimp and white shrimp were also substantial in the cages, but no differences in growth among the plots were apparent.

In general, the results of this experimental study indicated that annelid populations present at the time we conducted experiments were not providing food to predators such as juvenile brown shrimp, white shrimp, and blue crabs. In fact, blue crabs did not appear to be feeding on any of the infaunal organisms examined and may have been feeding on meiofauna. Differences in blue crab growth among the plots, however, suggested that the placement of dredged material on the bay bottom reduced the food value of the sediments for this species. Shrimp predators removed amphipods and small molluscs from the sediments. Growth rates of these predators were not significantly different among plots, but removal of prey was reduced at the experimental plots. This differential predation effect suggested that amphipods and molluscs inhabiting the dredge material were less accessible to shrimp predators.

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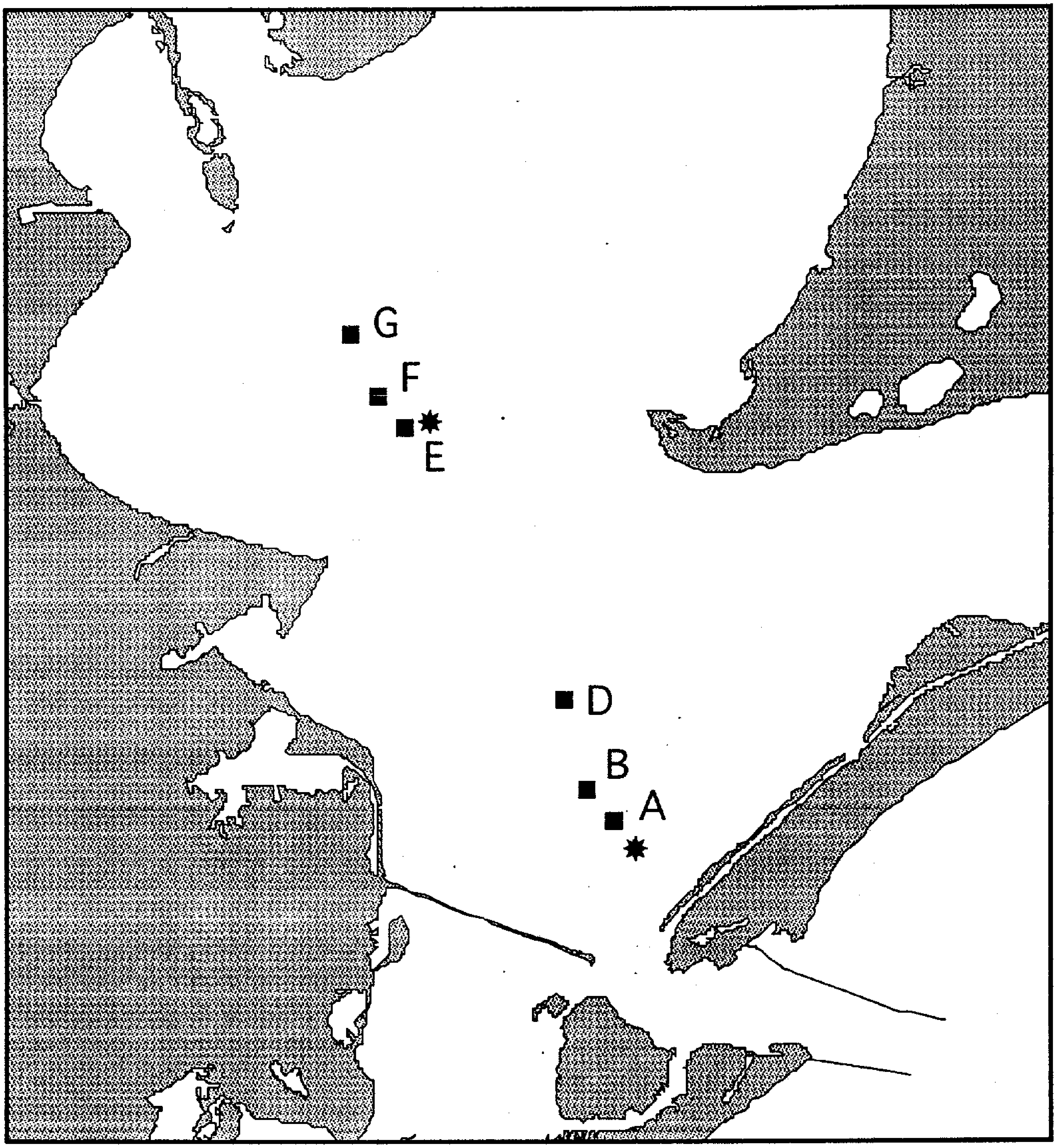
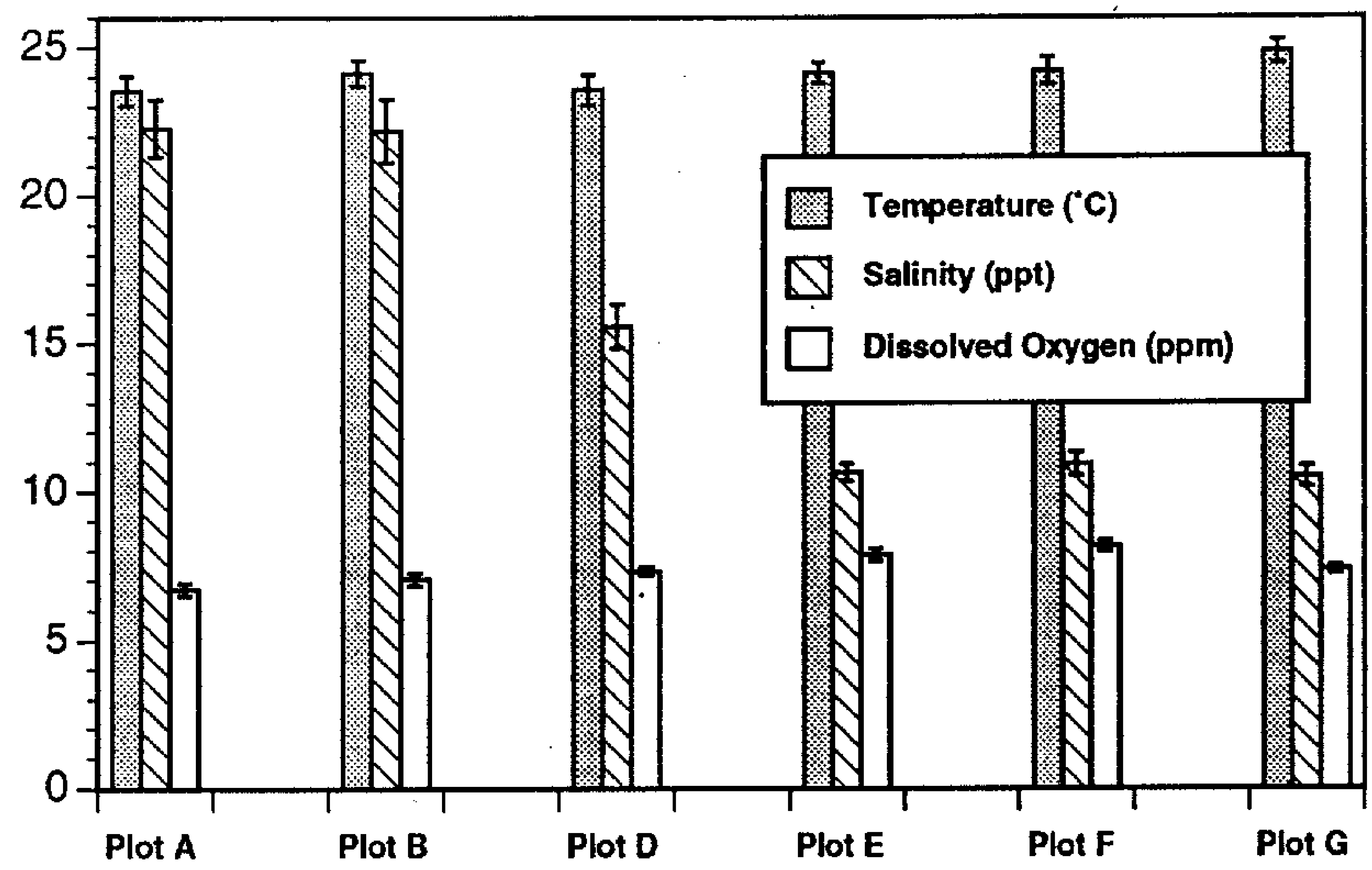


Figure 1. Locations of six plots in Galveston Bay where experimental caging study was conducted. Plots B and F contained dredged material. DataSondes used for measuring bottom water temperature, salinity, and dissolved oxygen were located near asterisks.



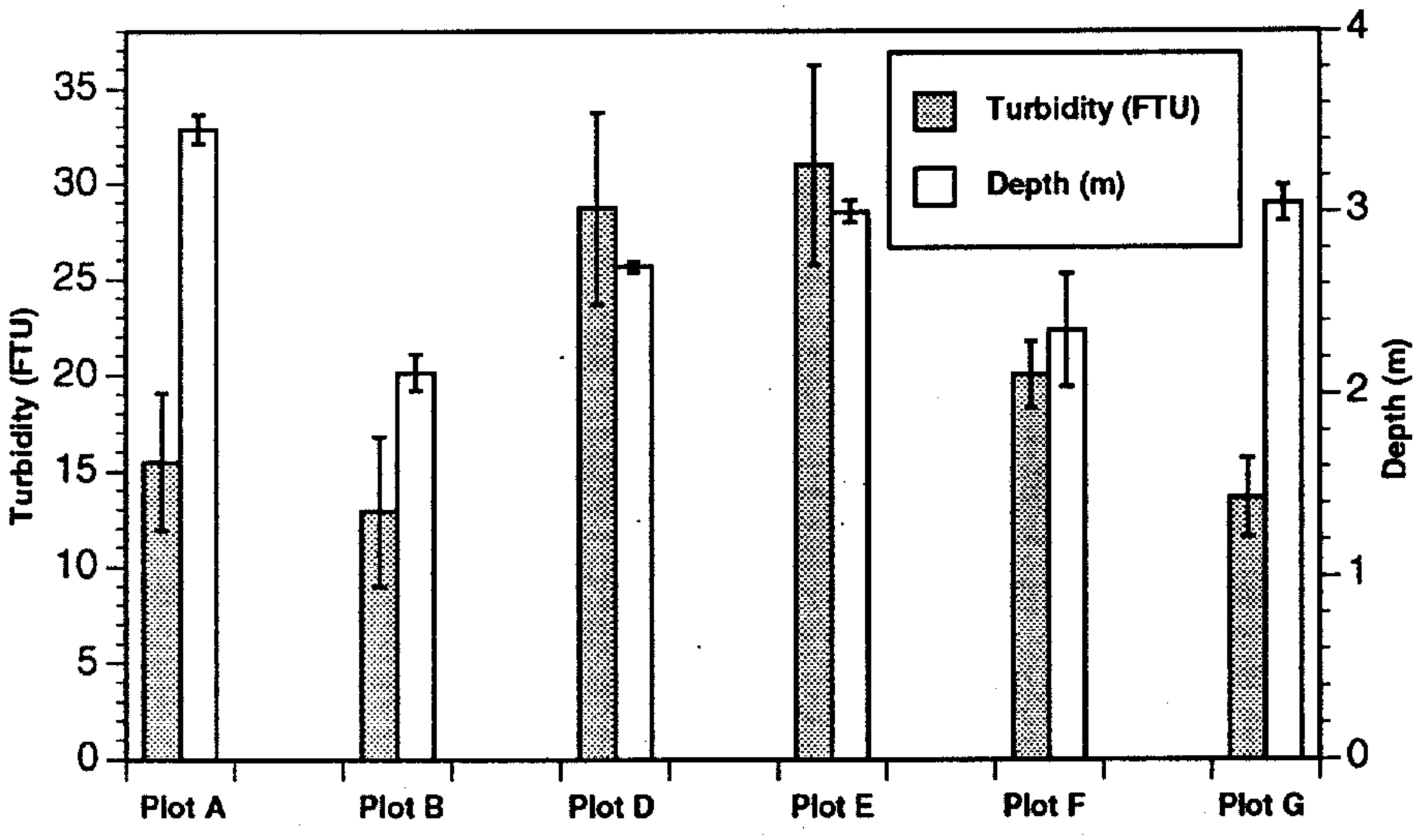


Figure 2: Water temperature, salinity, dissolved oxygen, turbidity, and depth at the experimental (B and F) and control plots in Galveston Bay during deployment and retrieval of cages for spring 1992 (May 8 to May 19). Error bars represent ± 1 SE.

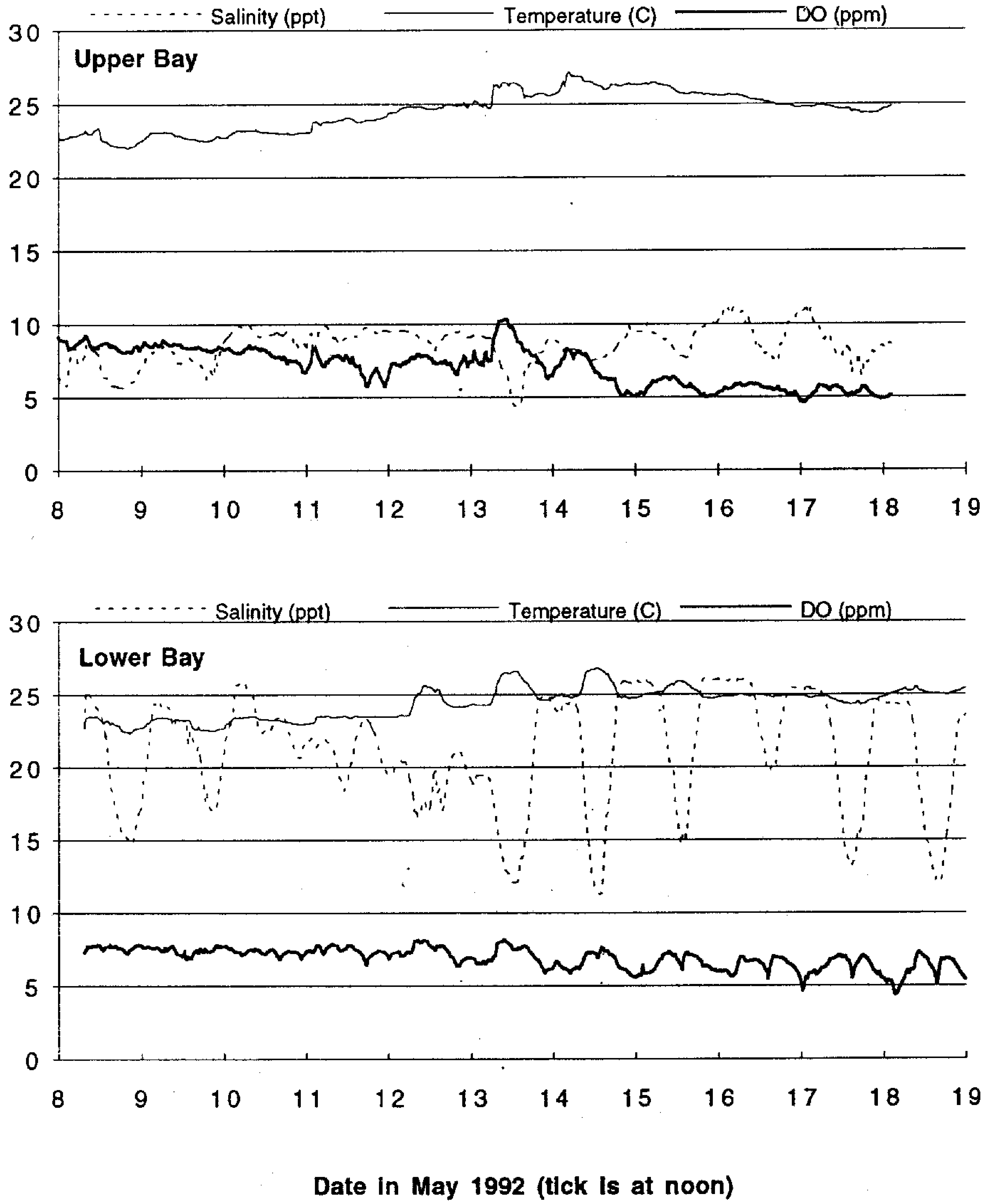


Figure 3. Continuous record of bottom water salinity, temperature, and dissolved oxygen in upper and lower Galveston Bay during the spring predation experiment. See Figure 1 for locations of recorders.

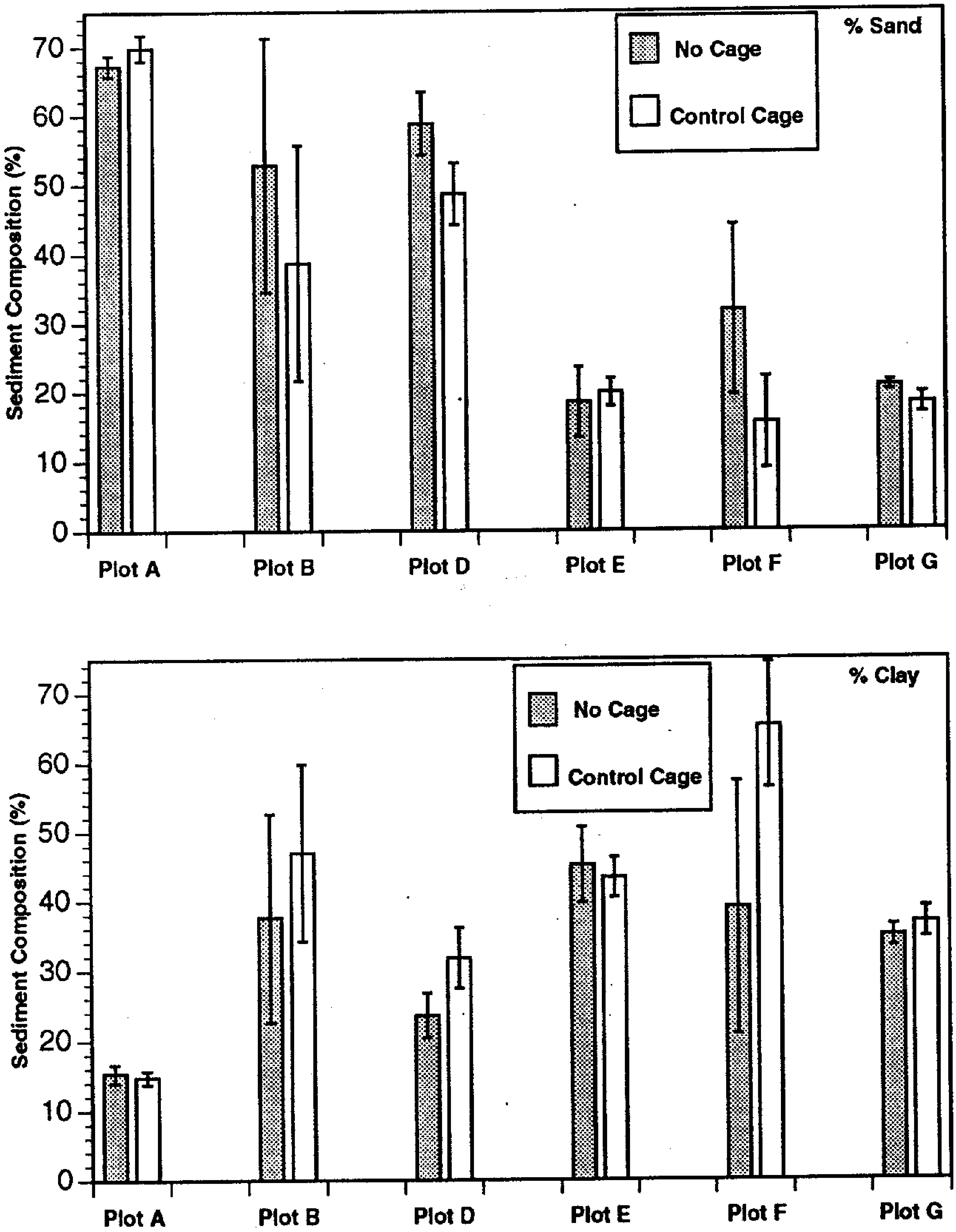


Figure 4: Mean sand and silt percentages for natural (No Cage) sediment samples and control cage sediment samples in experimental (B and F) and control plots in Galveston Bay for spring 1992. Error bars represent ± 1 SE, N= 4 for each mean.

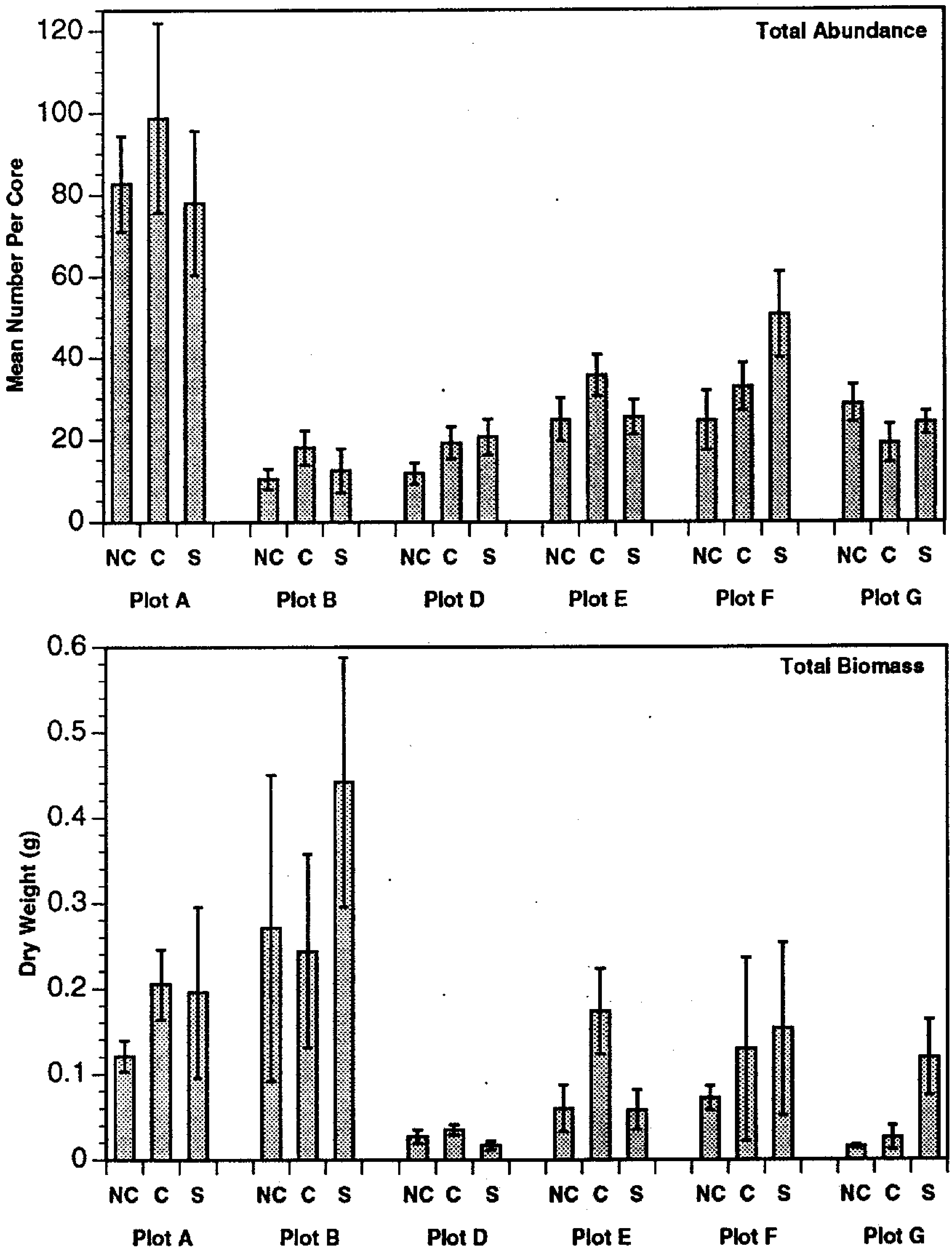
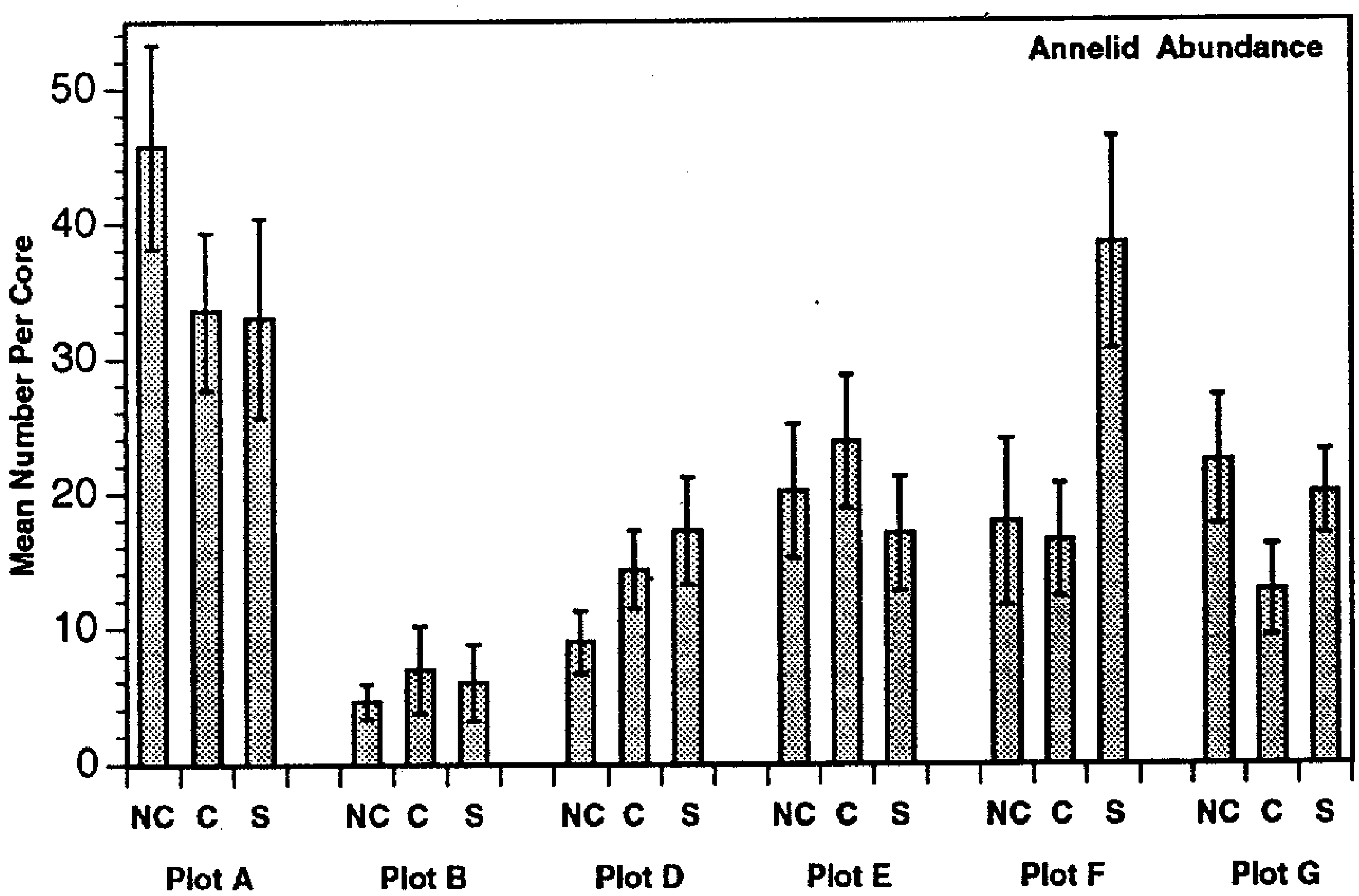


Figure 5: Abundance (number per 0.031 m^2) and biomass (g dry weight) of total infauna from different treatments at experimental (B and F) and control plots in Galveston Bay for spring 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), and Shrimp cage (S).



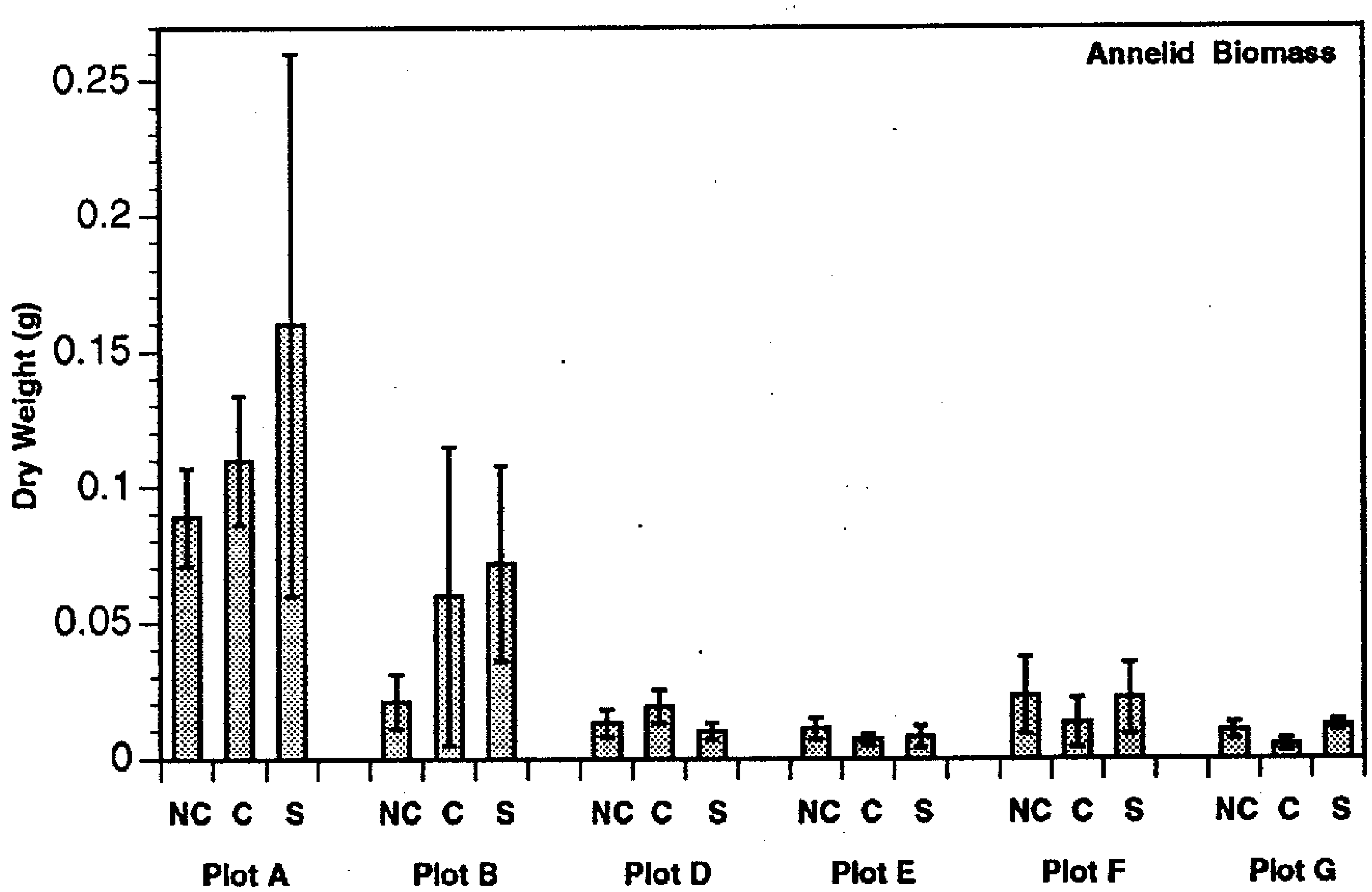


Figure 6: Abundance (number per $0.031m^2$) and biomass (g dry weight) of annelids from different treatments at experimental (B and F) and control plots in Galveston Bay for spring 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), and Shrimp cage (S).

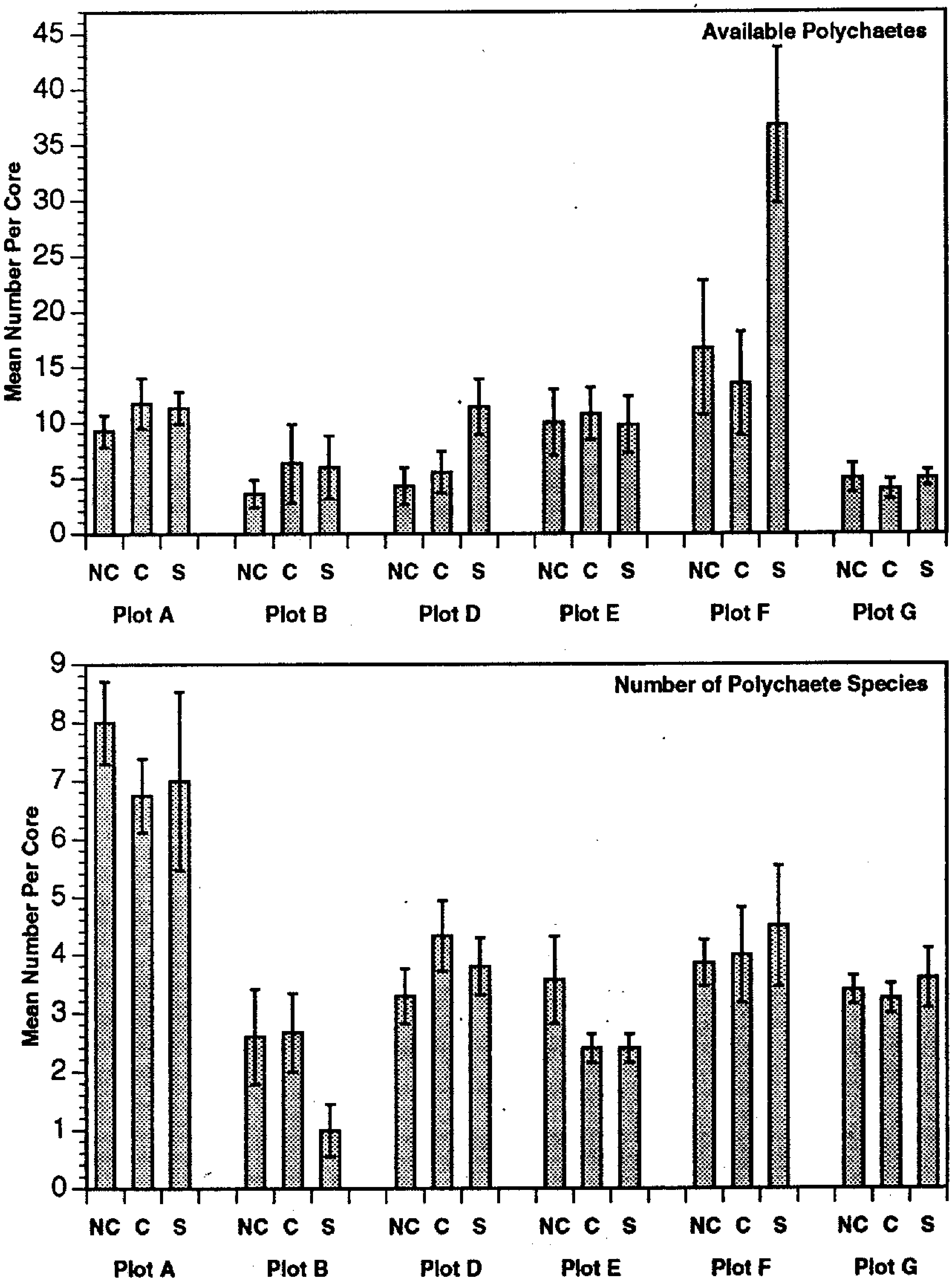
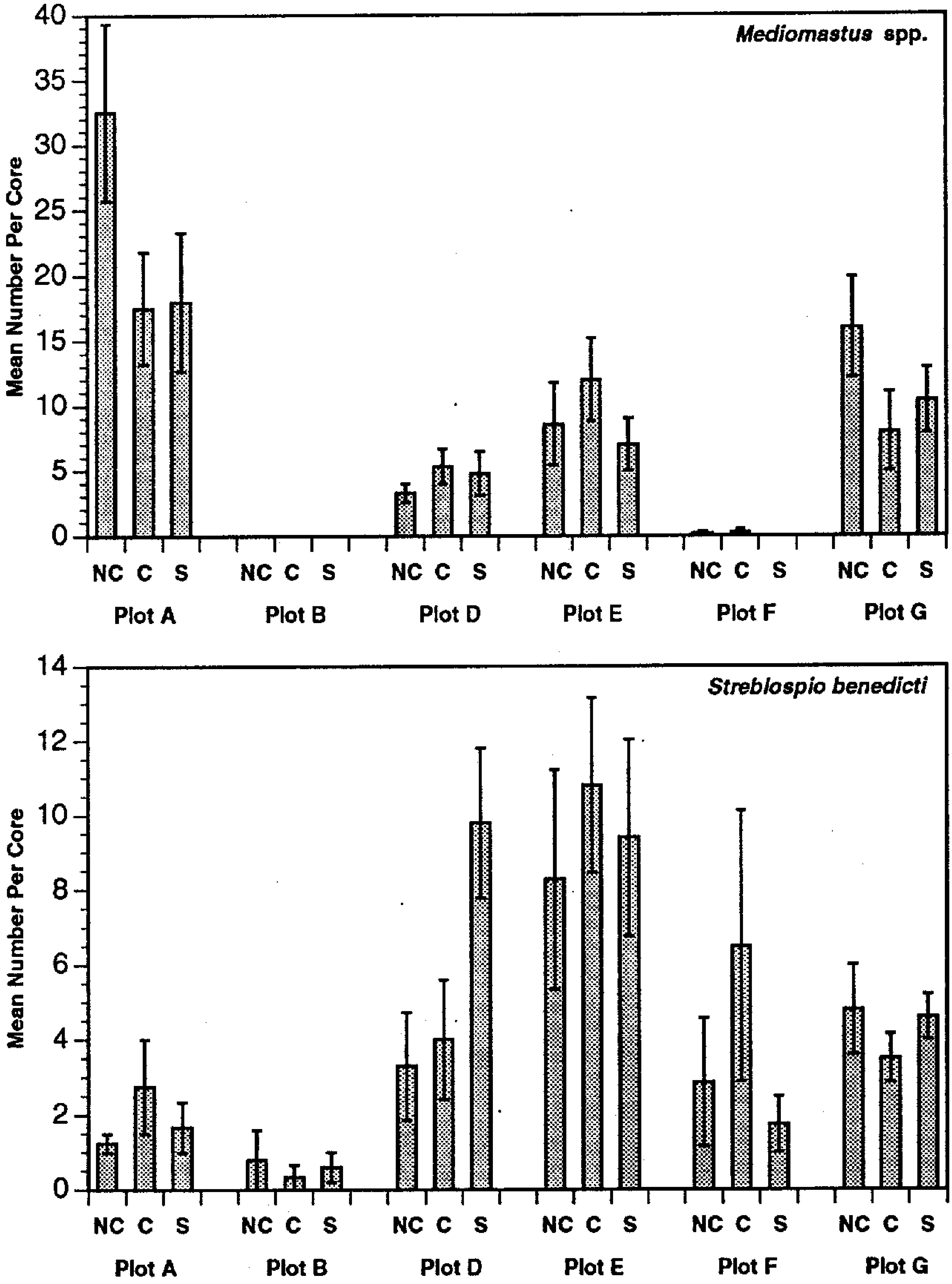


Figure 7: Abundance (number per $0.031m^2$) of polychaetes available to predators (See Table 2) and the number of polychaete species identified from different treatments at experimental (B and F) and control plots in Galveston Bay for spring 1992.



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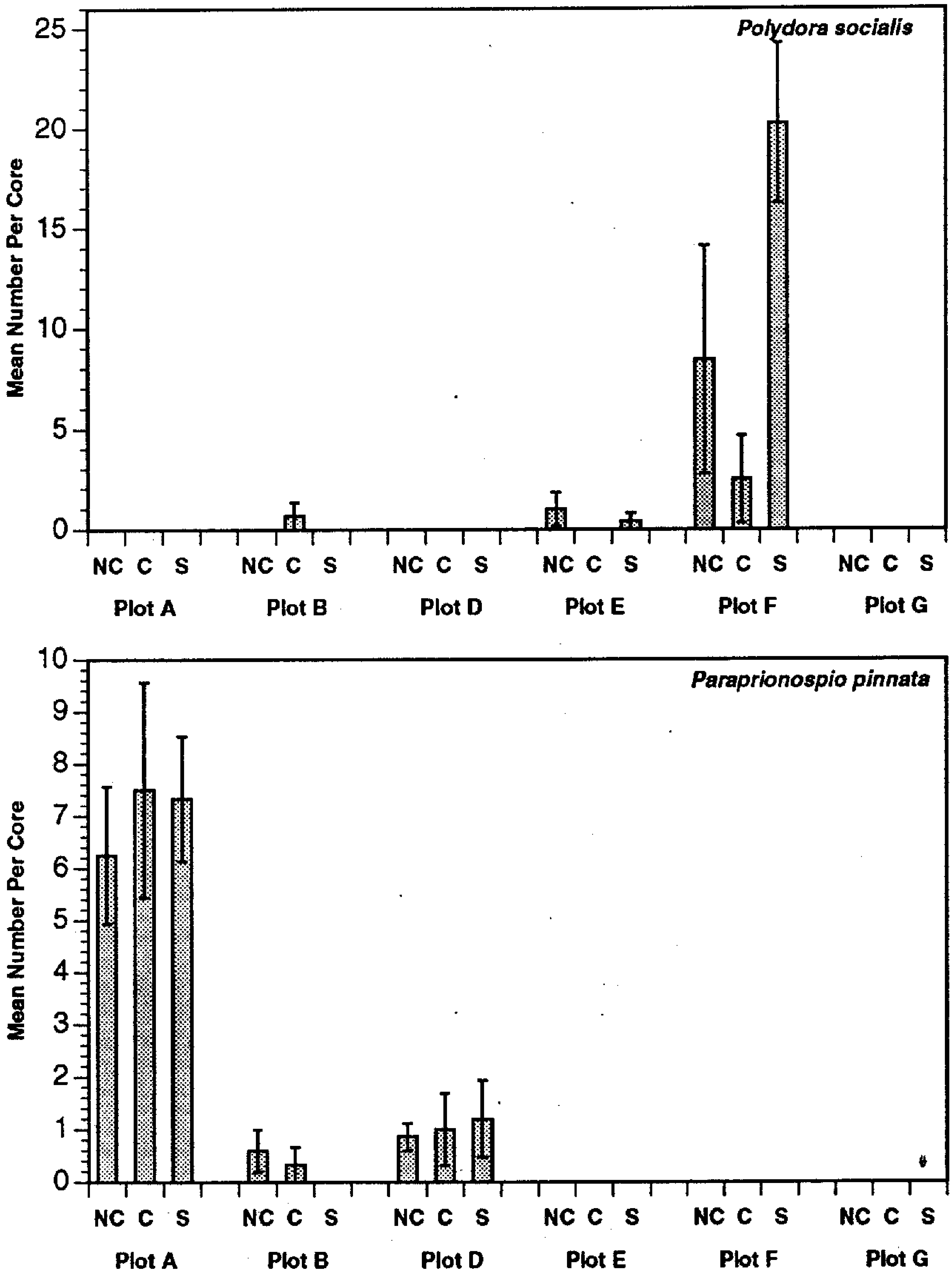


Figure 9: Abundance (number per $0.031m^2$) of the polychaetes *Polydora socialis* and *Paraprionospio pinnata* from different treatments at experimental (B and F) and control plots in Galveston Bay for spring 1992. Mean values are shown (See Table 1 for Ns), error bars represent ±1 SE. Treatments included no cage (NC), control cage (C), and shrimp cage (S).

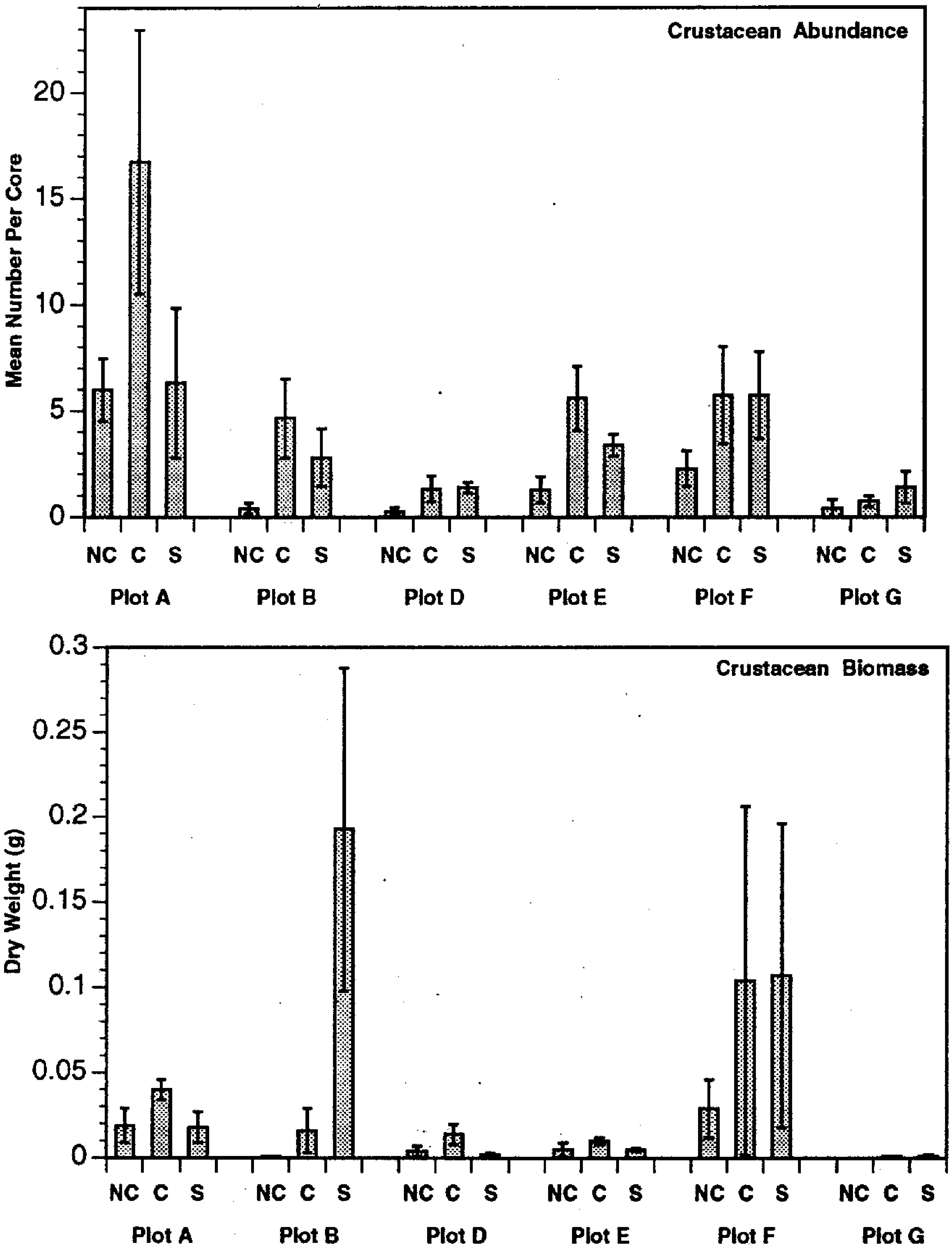
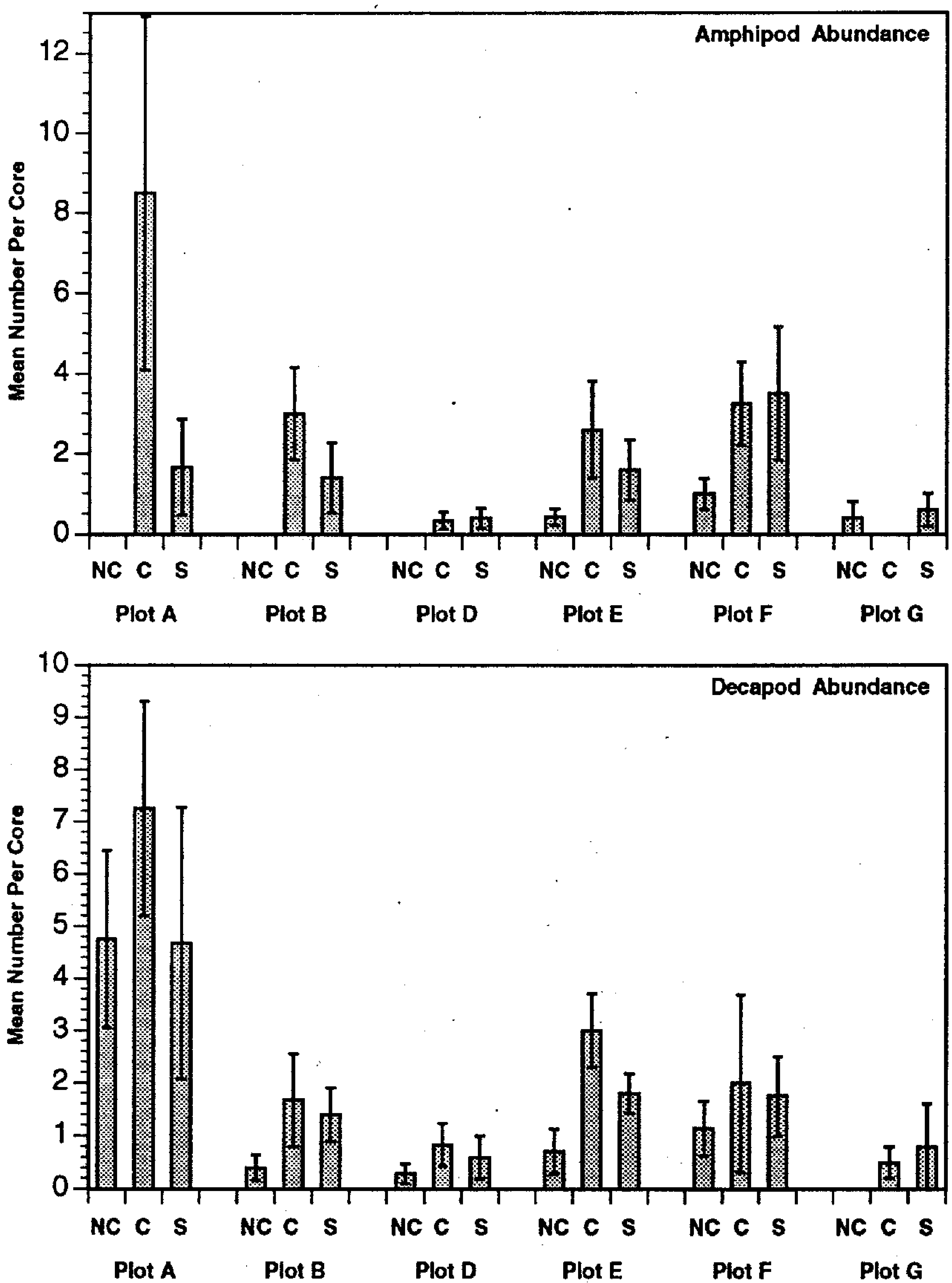


Figure 10: Abundance (number per $0.031m^2$) and biomass (g dry weight) of crustaceans from different treatments at experimental (B and F) and control plots in Galveston Bay for spring 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), and Shrimp cage (S).



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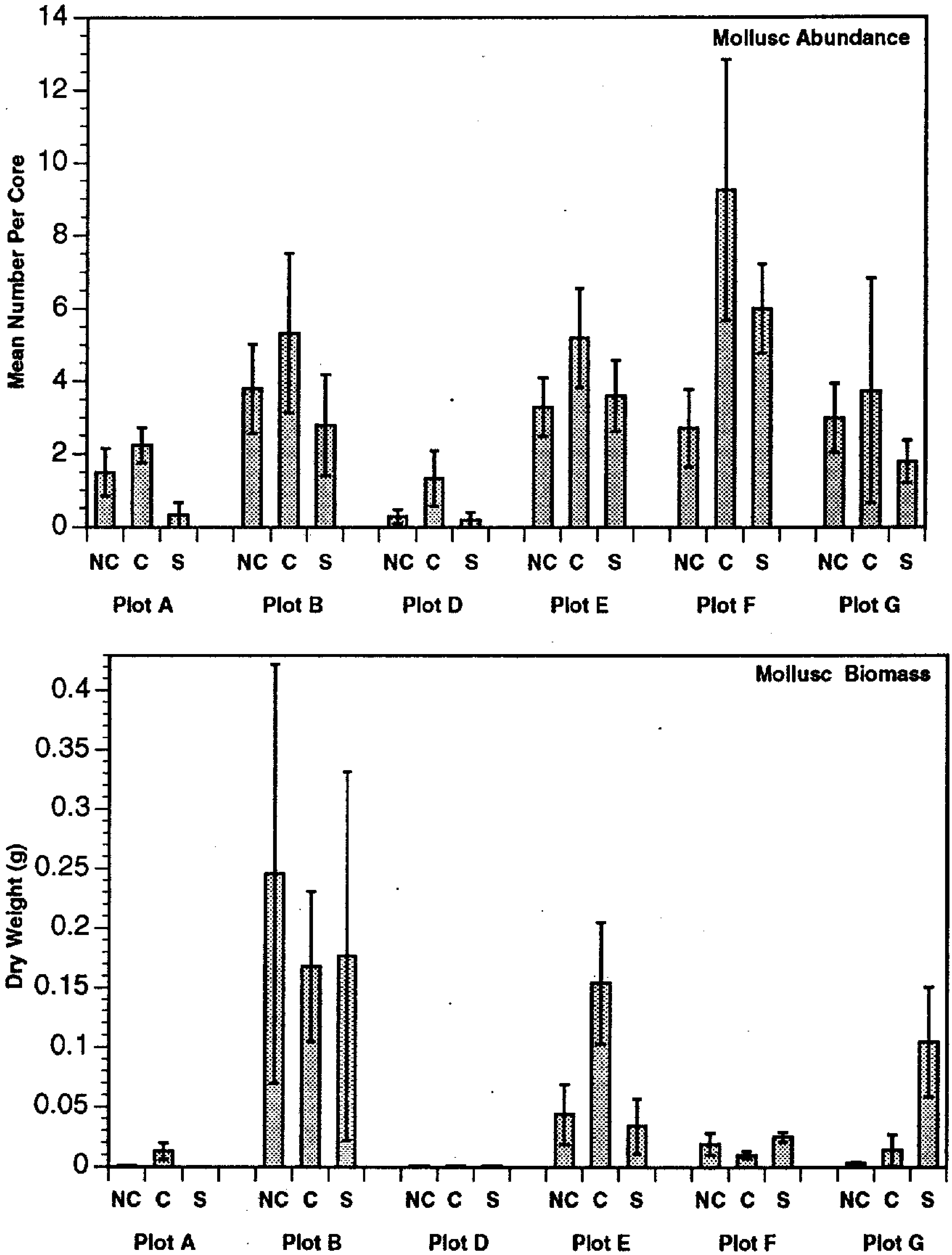
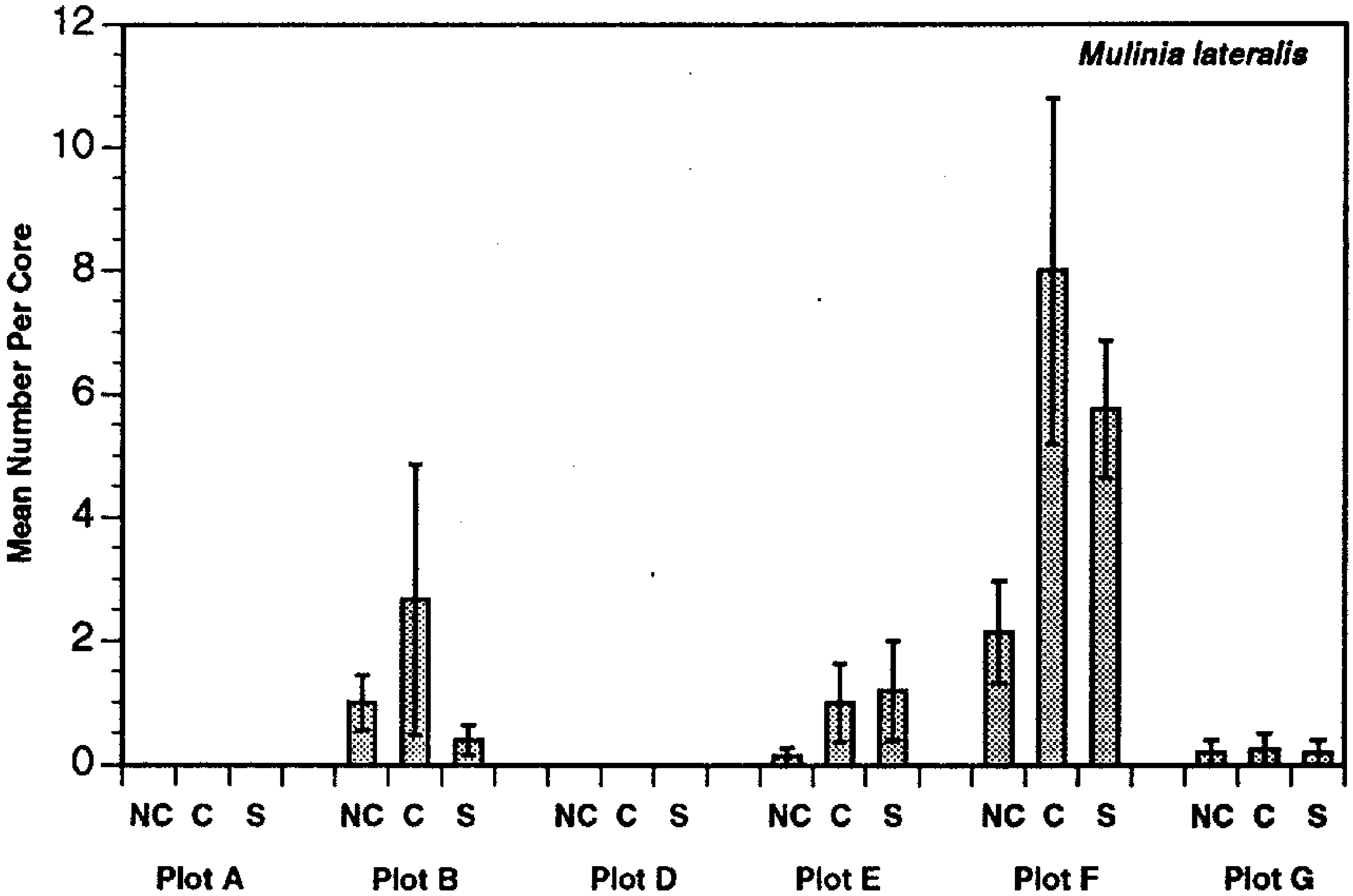


Figure 12: Abundance (number per $0.031m^2$) and biomass (g dry weight) of molluscs from different treatments at experimental (B and F) and control plots in Galveston Bay for spring 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), and Shrimp cage (S).



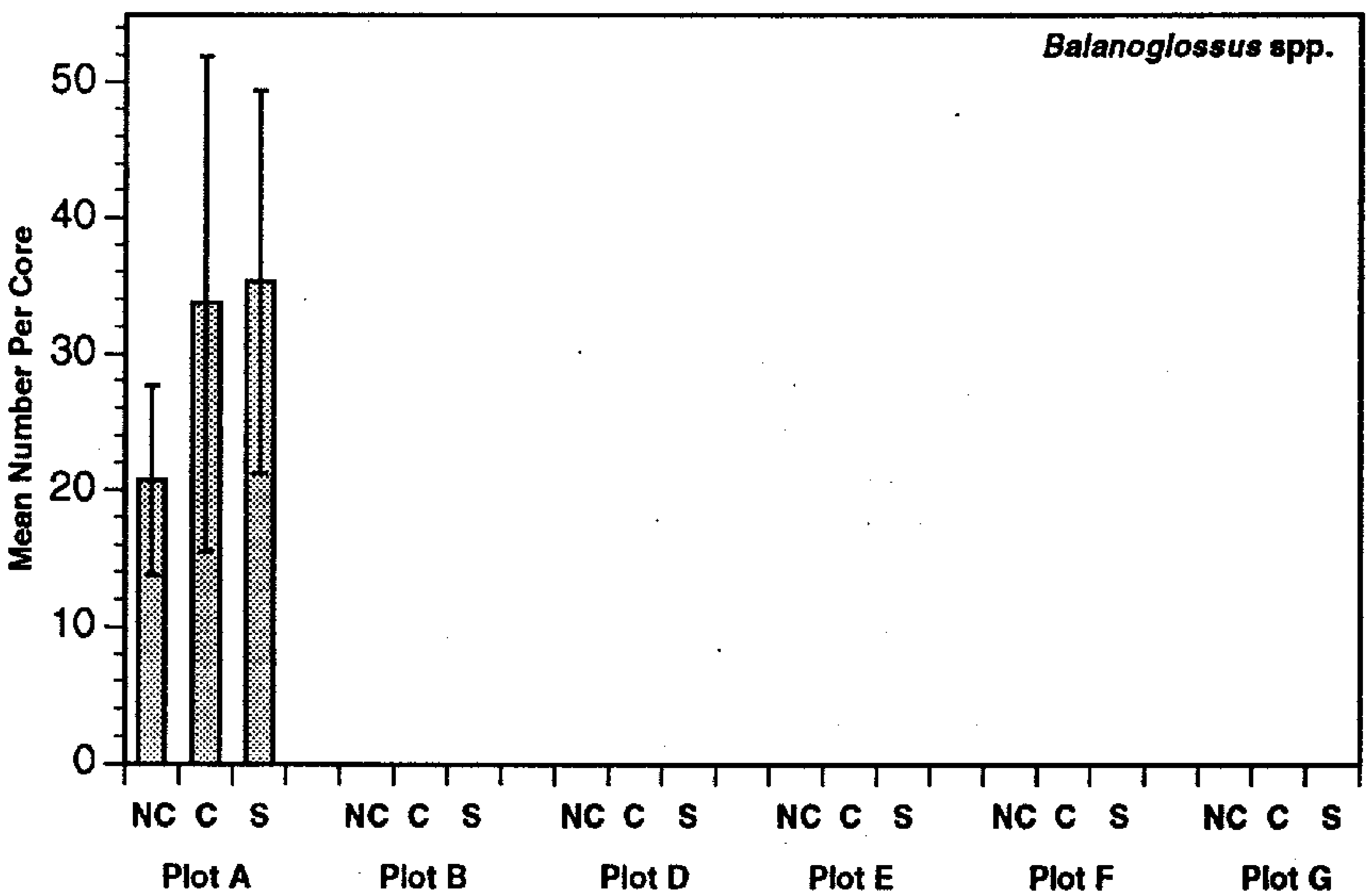


Figure 13: Abundance (number per $0.031 m^2$) of the mollusc *Mulinia lateralis* and the hemichordate *Balanoglossus* spp. from different treatments at experimental (B and F) and control plots in Galveston Bay for spring 1992. Mean values are shown (See Table 1 for Ns), error bars represent ±1 SE. Treatments included no cage (NC), control cage (C), and shrimp cage (S).

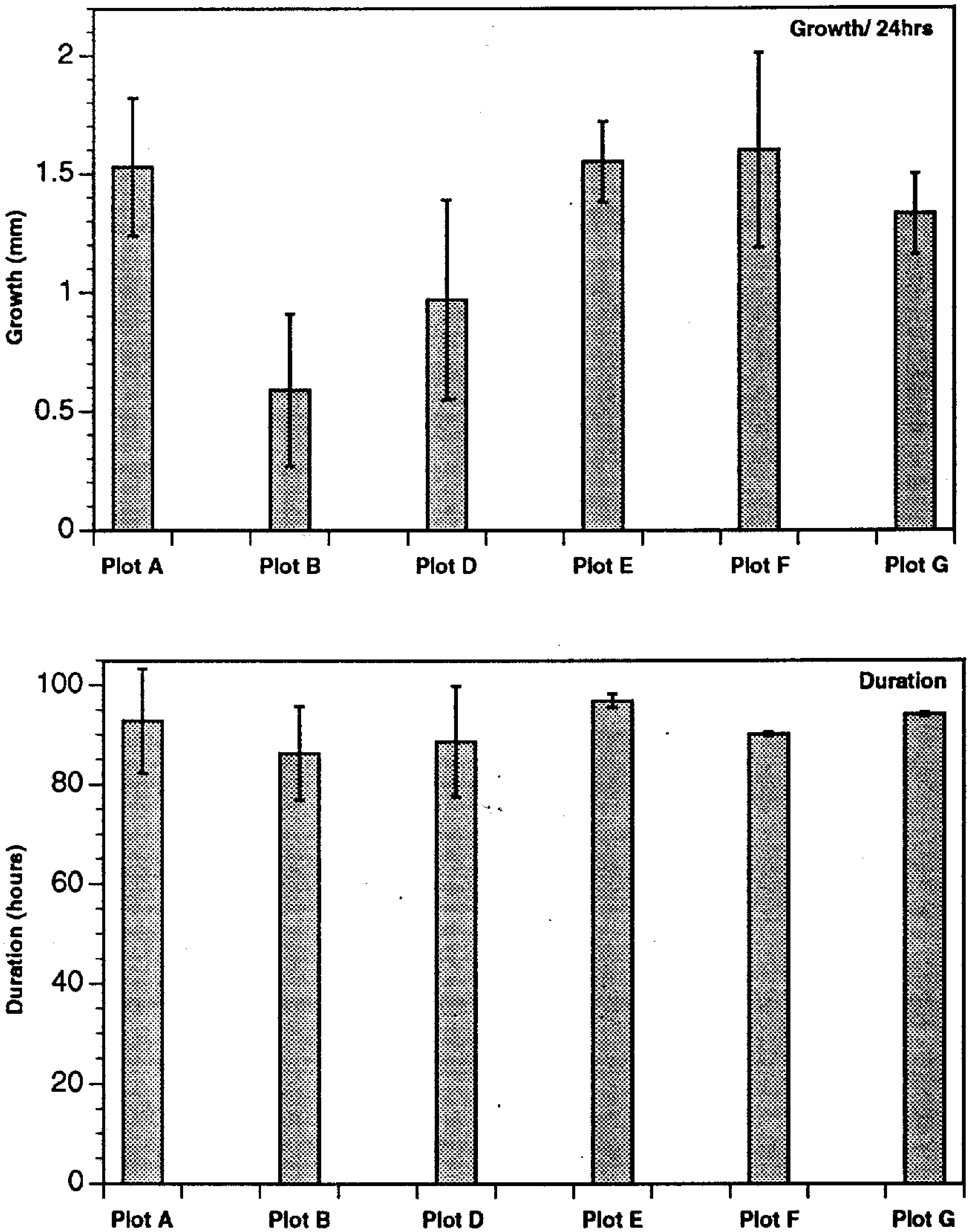


Figure 14: Mean brown shrimp growth (mm per 24 hrs) and mean experimental duration at experimental (B and F) and control plots in Galveston Bay during spring 1992. Error bars represent ± 1 SE.

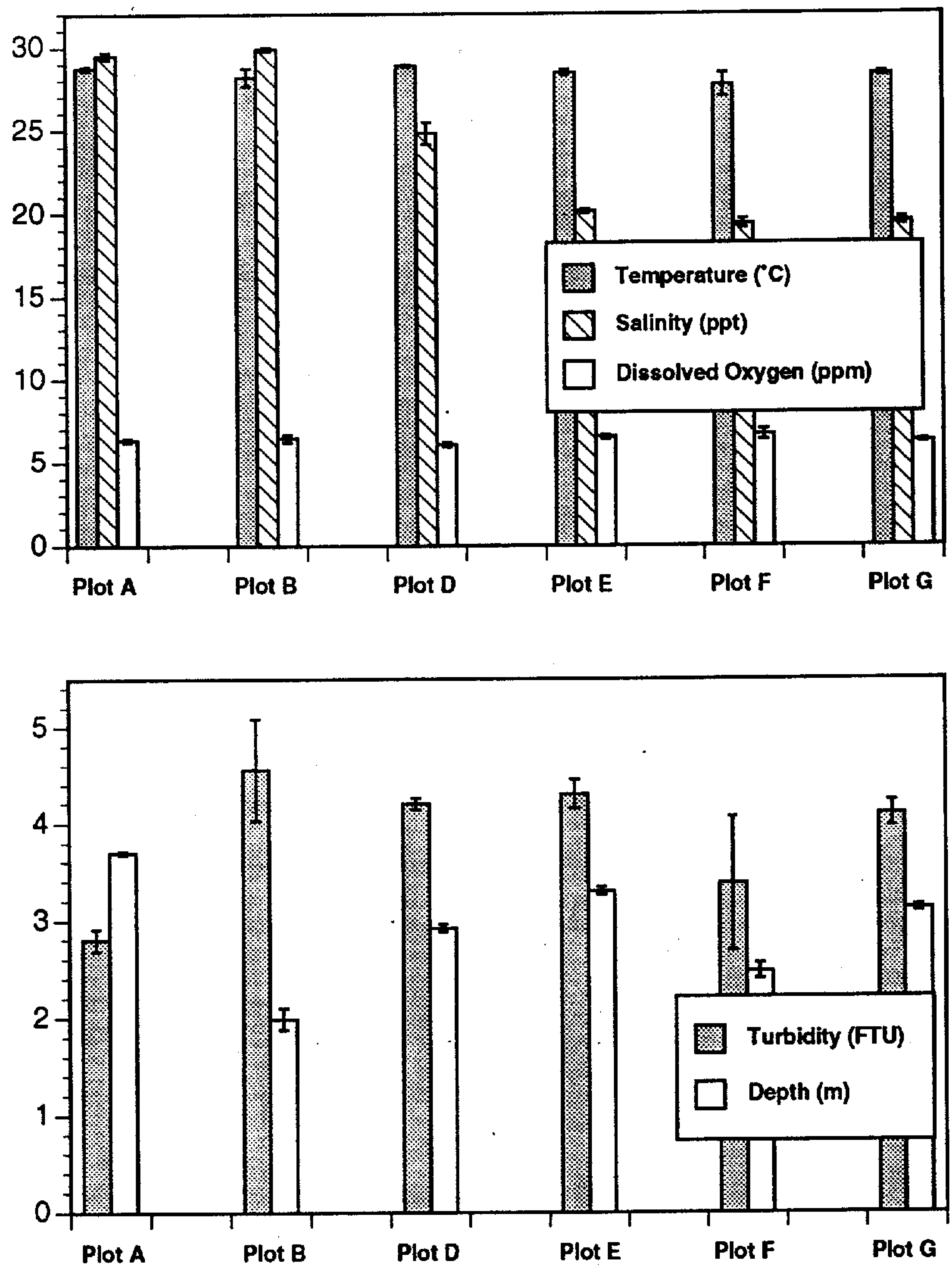
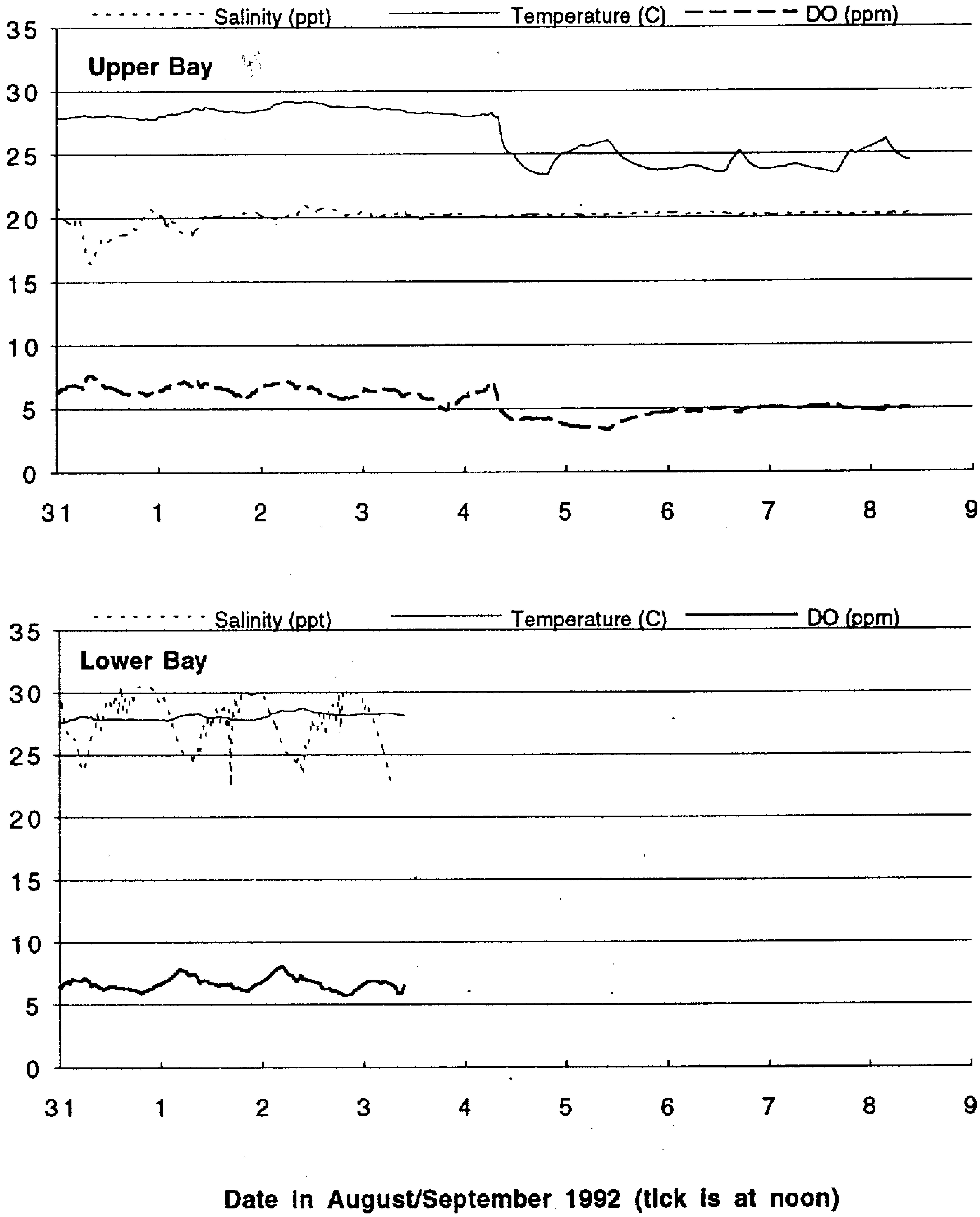


Figure 15: Water temperature, salinity, dissolved oxygen, turbidity, and depth at the experimental (B and F) and control plots in Galveston Bay during deployment and retrieval of cages for Fall 1992 (August 31 to September 5). Error bars represent ± 1 SE.



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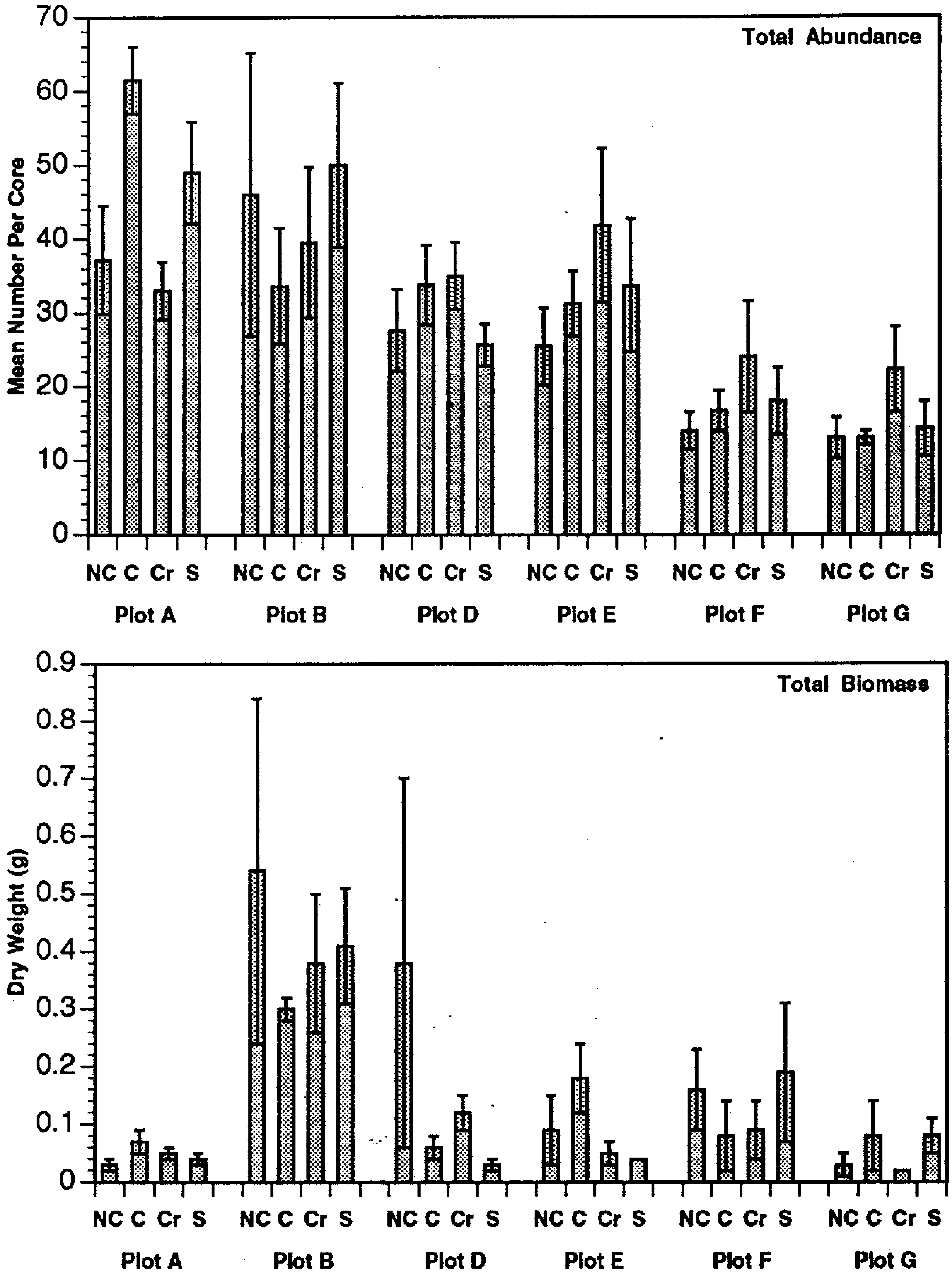

Figure 17: Abundance (number per $0.031m^2$) and biomass (g dry weight) of total infauna from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), Crab Cage (Cr), and Shrimp cage (S).

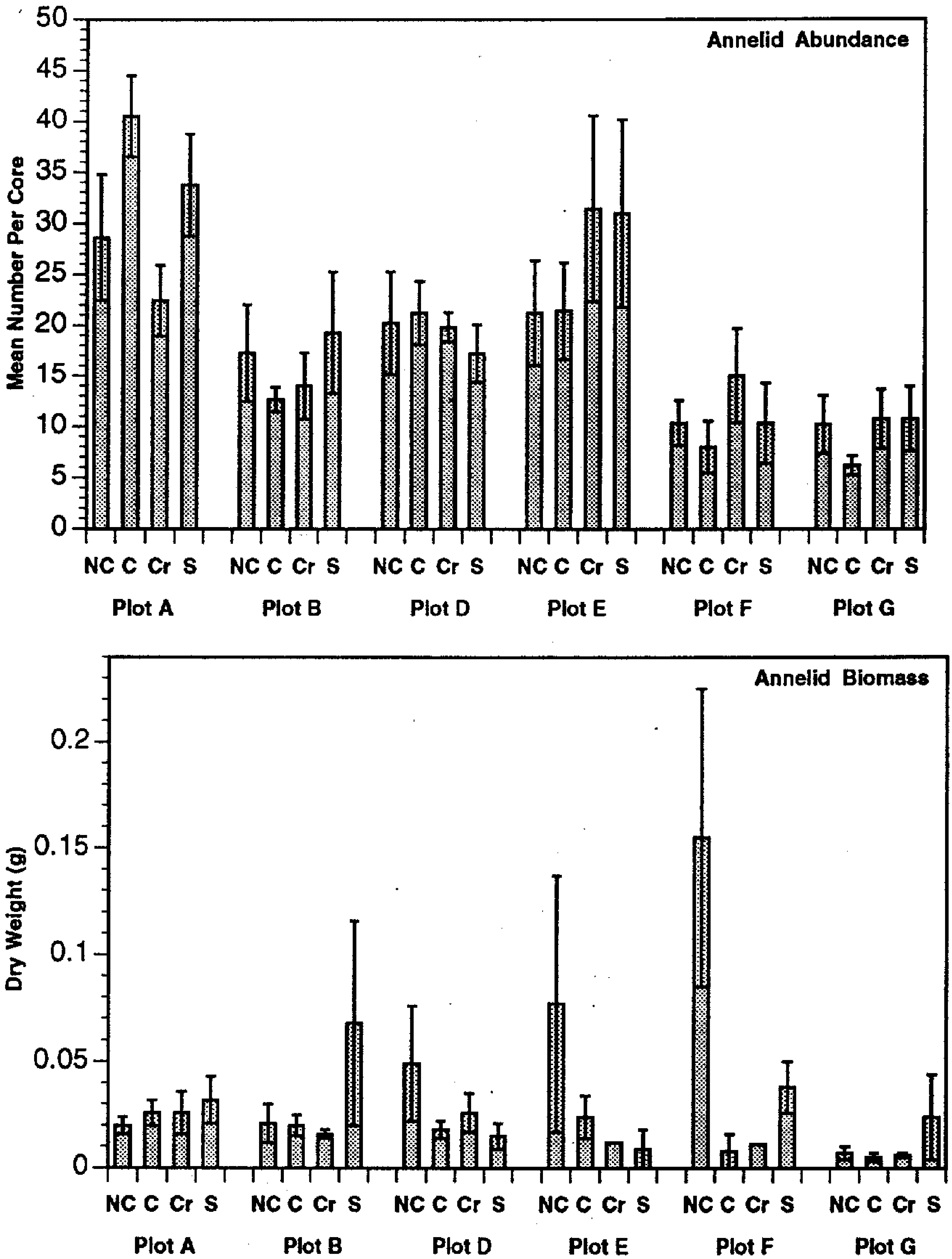

Figure 18: Abundance (number per $0.031m^2$) and biomass (g dry weight) of annelids from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), Crab Cage (Cr), and Shrimp cage (S).

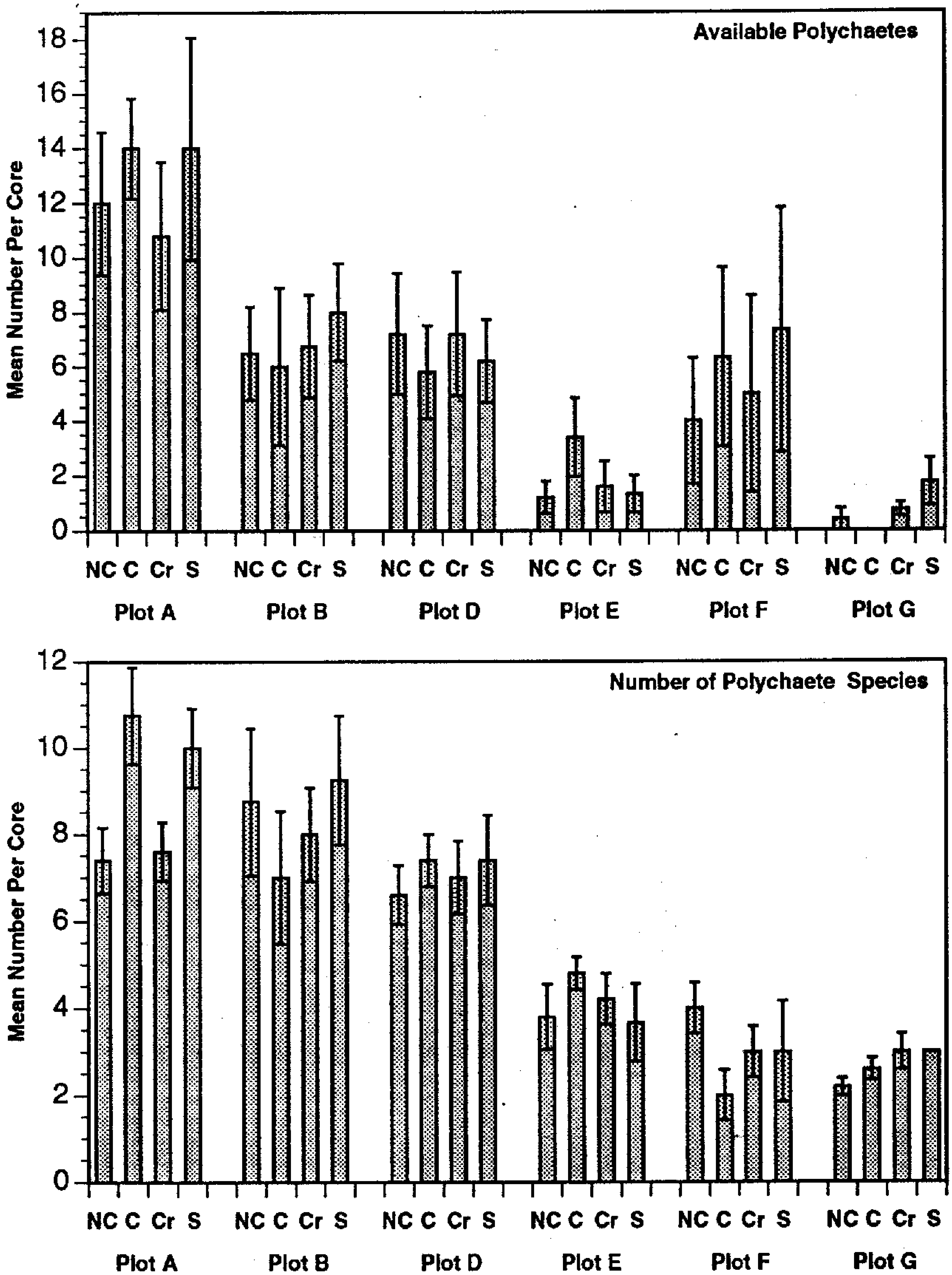

Figure19: Abundance (number per $0.031m^2$) of polychaetes available to predators (See Table 2) and the number of polychaete species identified from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992.

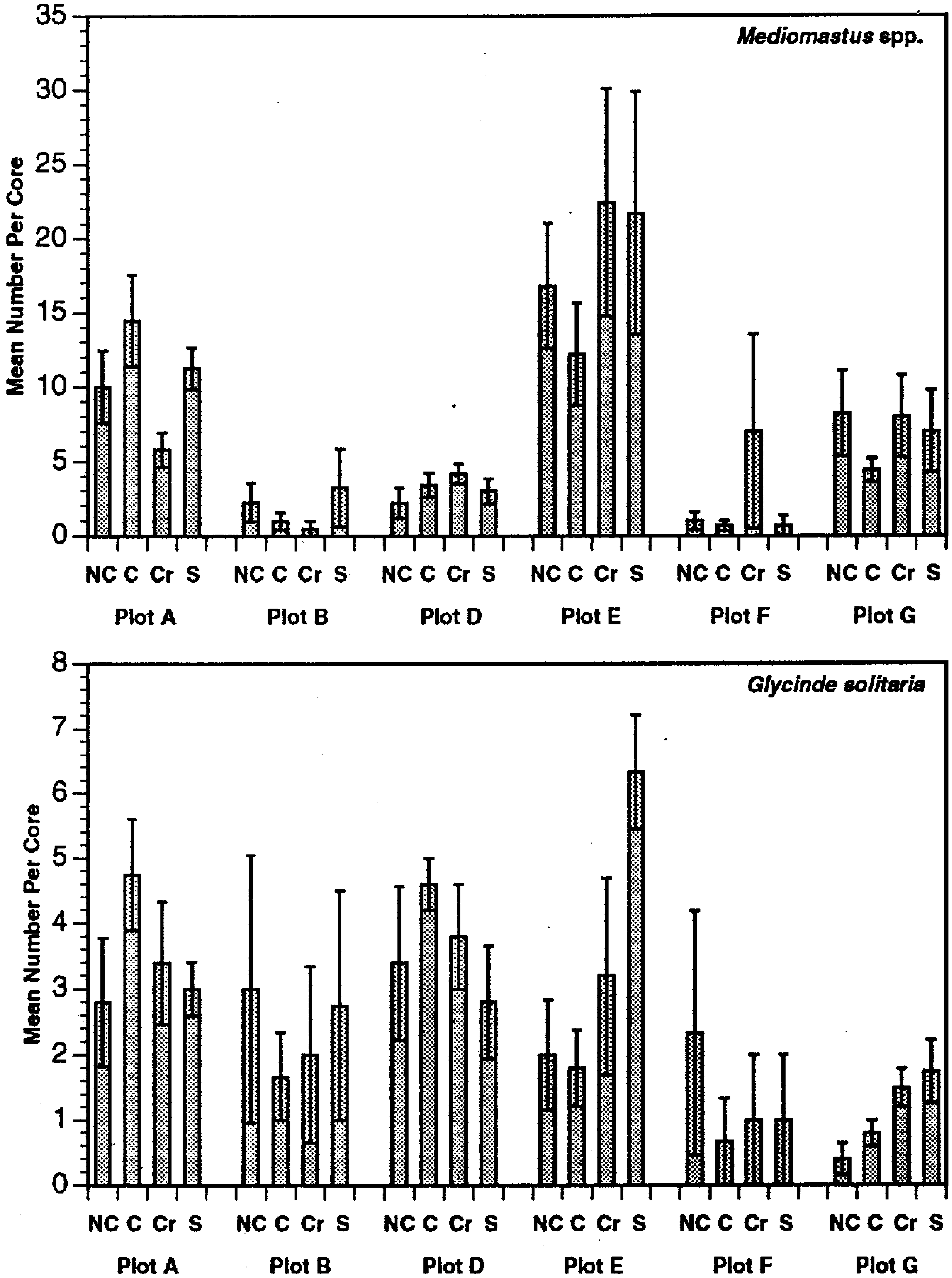

Figure 20: Abundance (number per $0.031m^2$) of *Mediomastus* spp. and *Glycinde solitaria* from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), Crab Cage (Cr), and Shrimp cage (S).

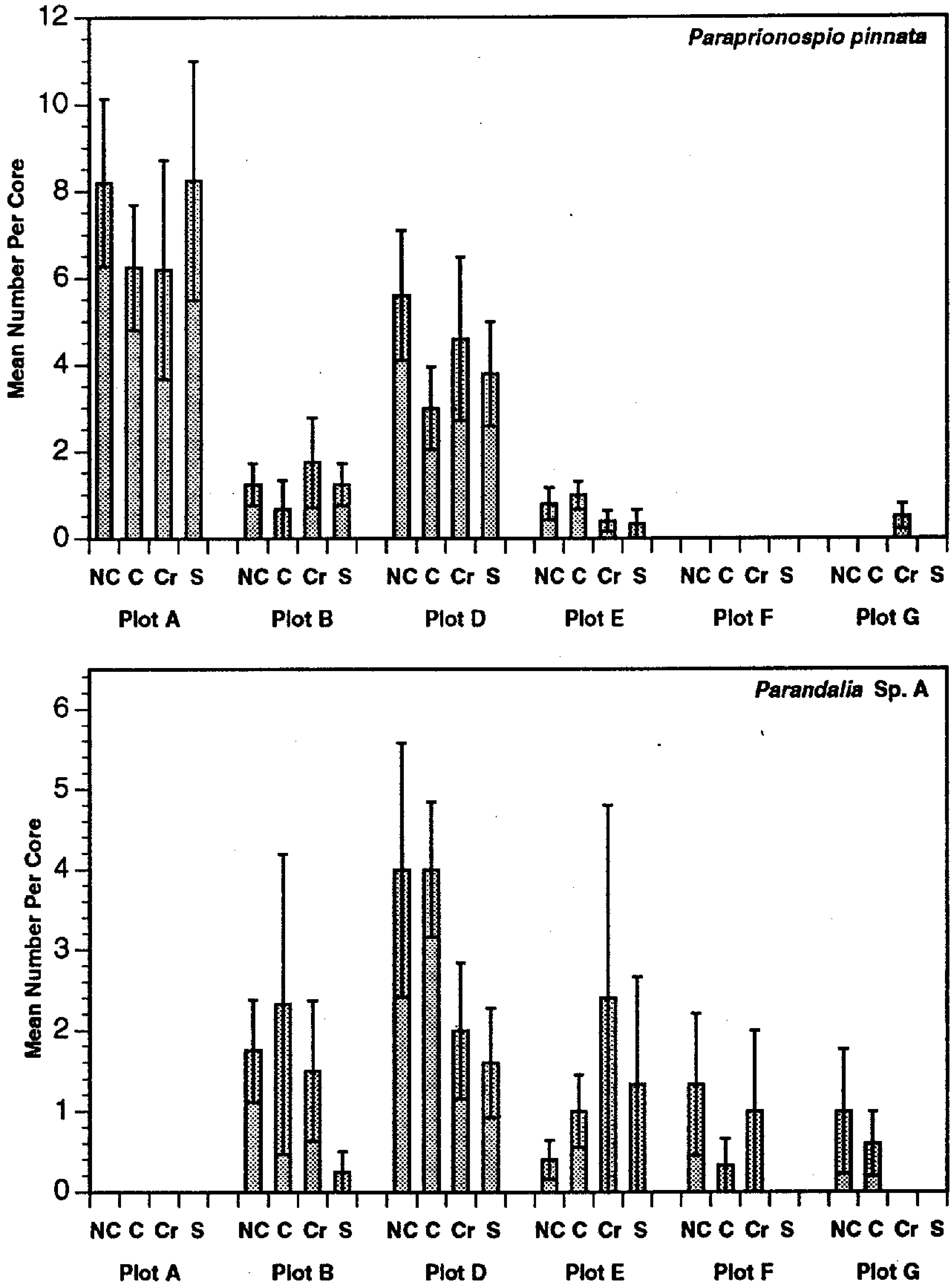

Figure 21: Abundance (number per $0.031m^2$) of *Paraprionospio pinnata* and *Parandalia* Sp. A from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), Crab Cage (Cr), and Shrimp cage (S).

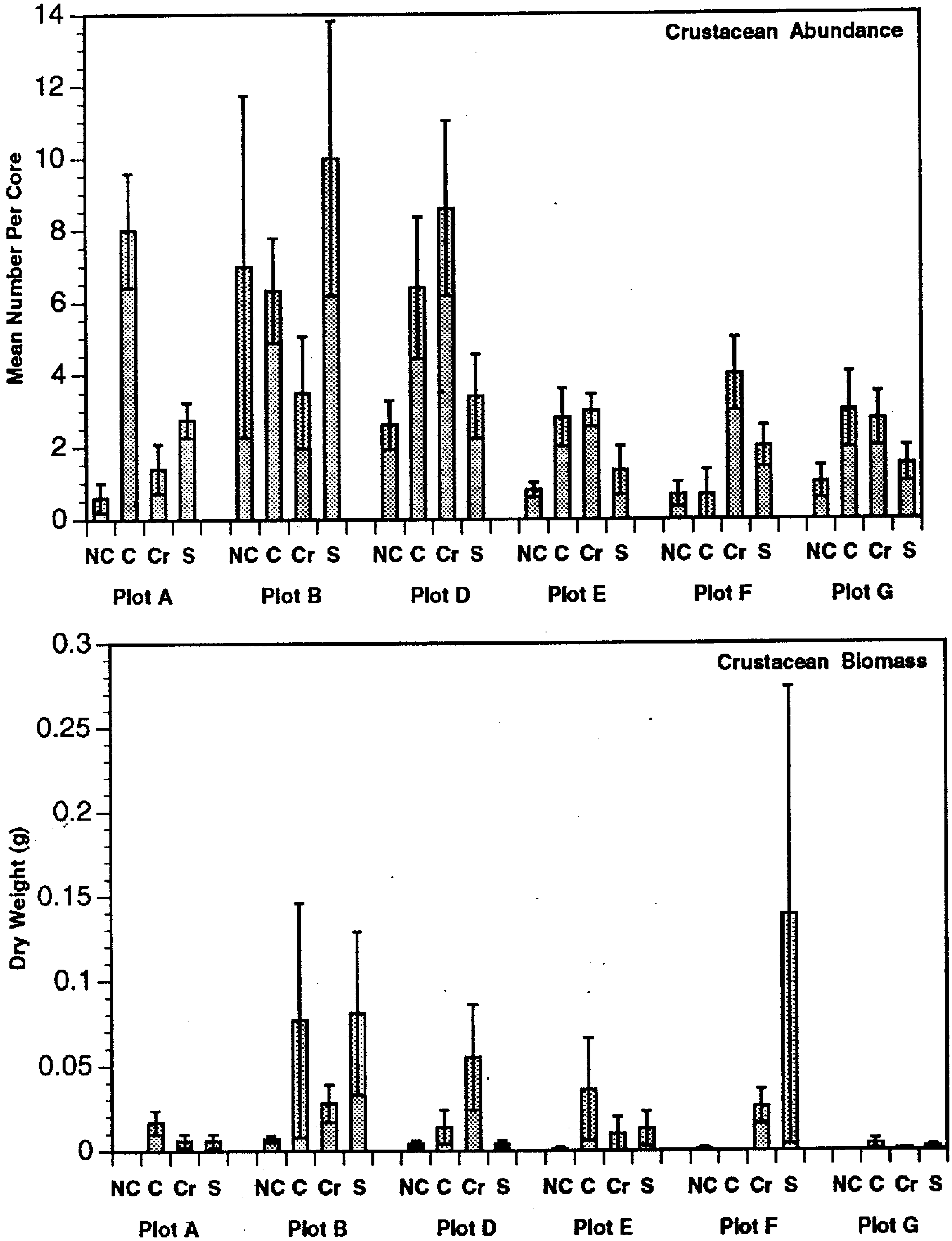

Figure 22: Abundance (number per $0.031m^2$) and biomass (g dry weight) of crustaceans from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), Crab Cage (Cr), and Shrimp cage (S).

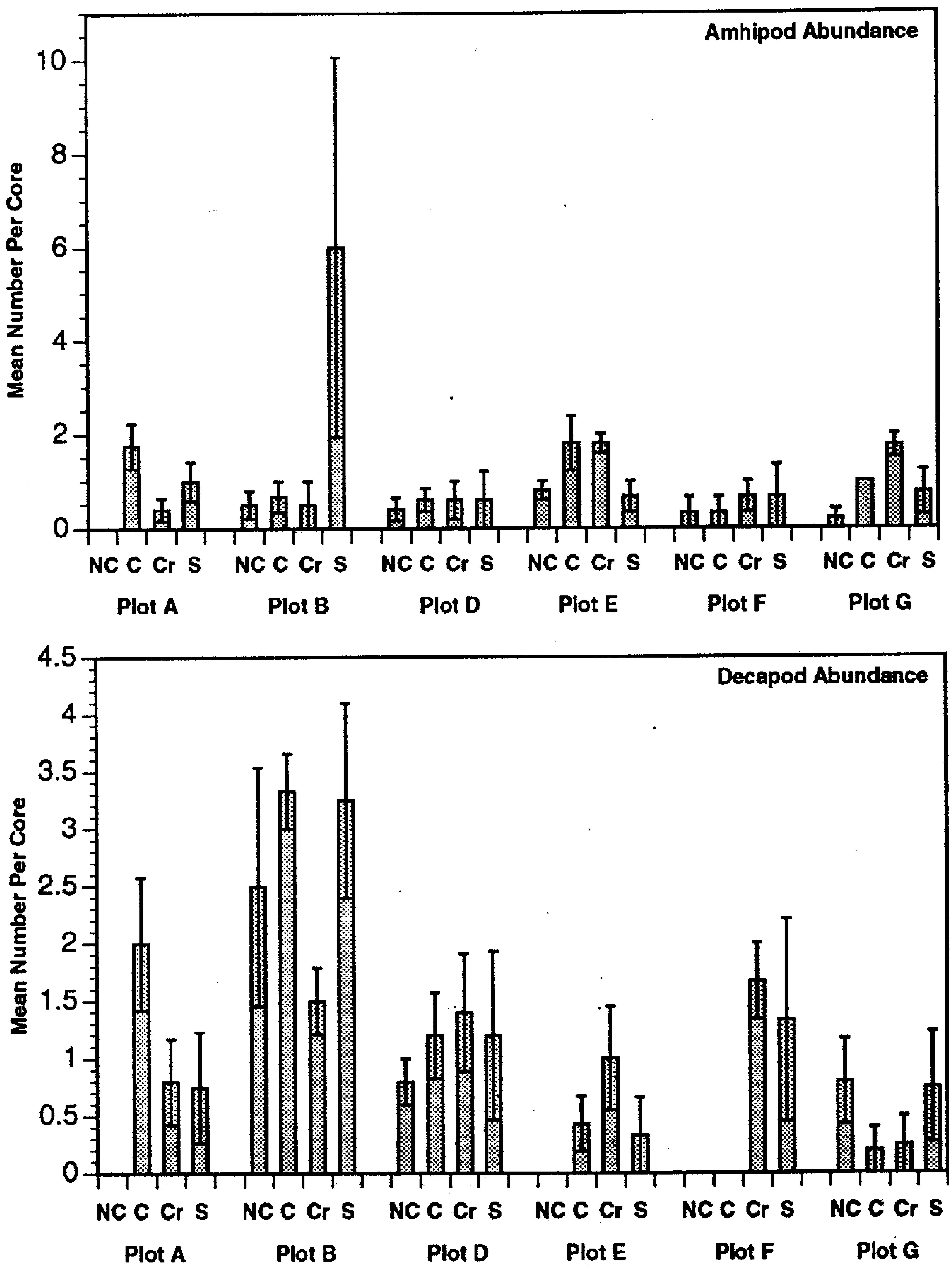

Figure 23: Abundance (number per $0.031m^2$) of amphipods and decapods from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), Crab Cage (Cr), and Shrimp cage (S).

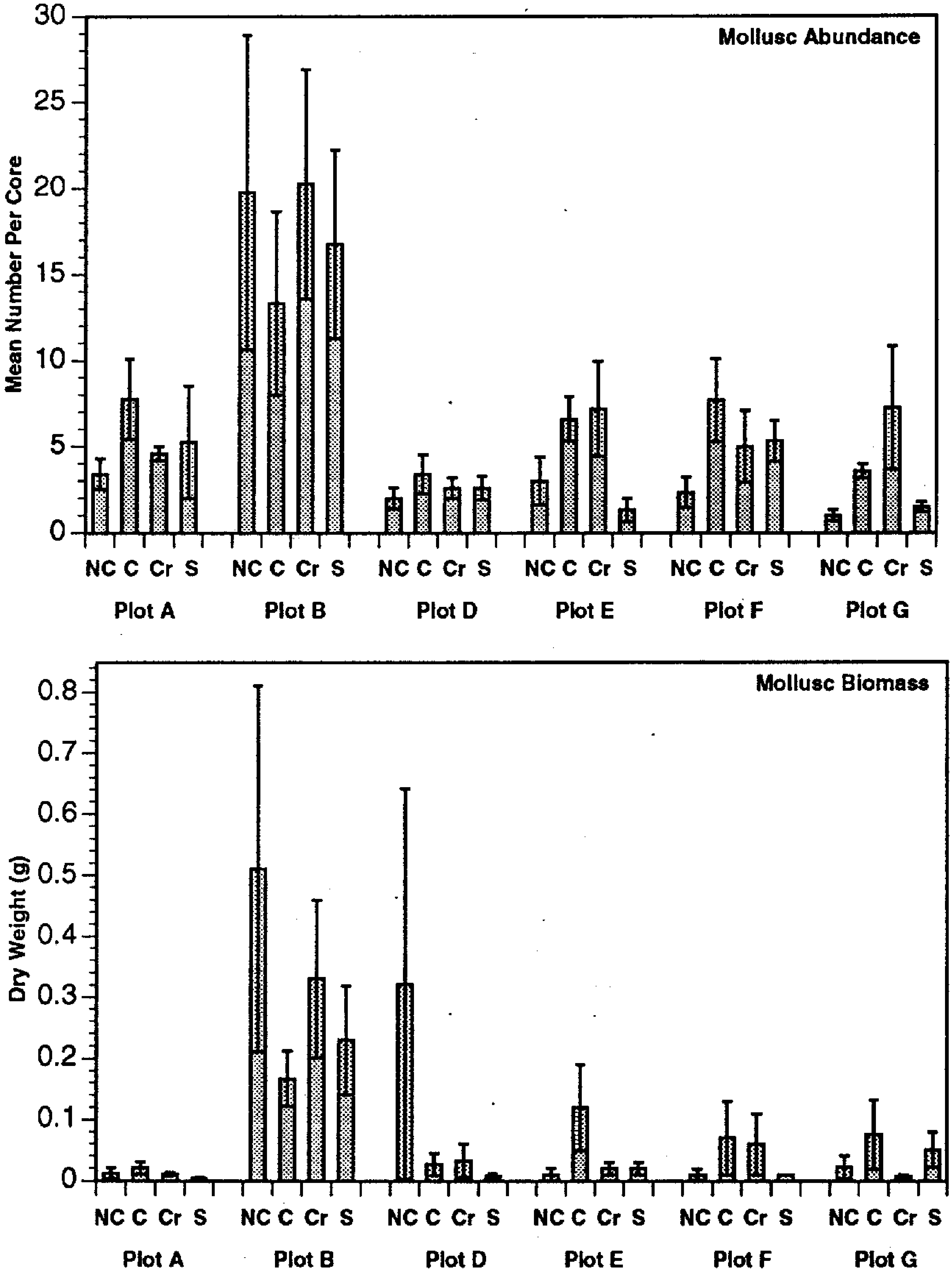

Figure 24: Abundance (number per $0.031m^2$) and biomass (g dry weight) of molluscs from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), Crab Cage (Cr), and Shrimp cage (S).

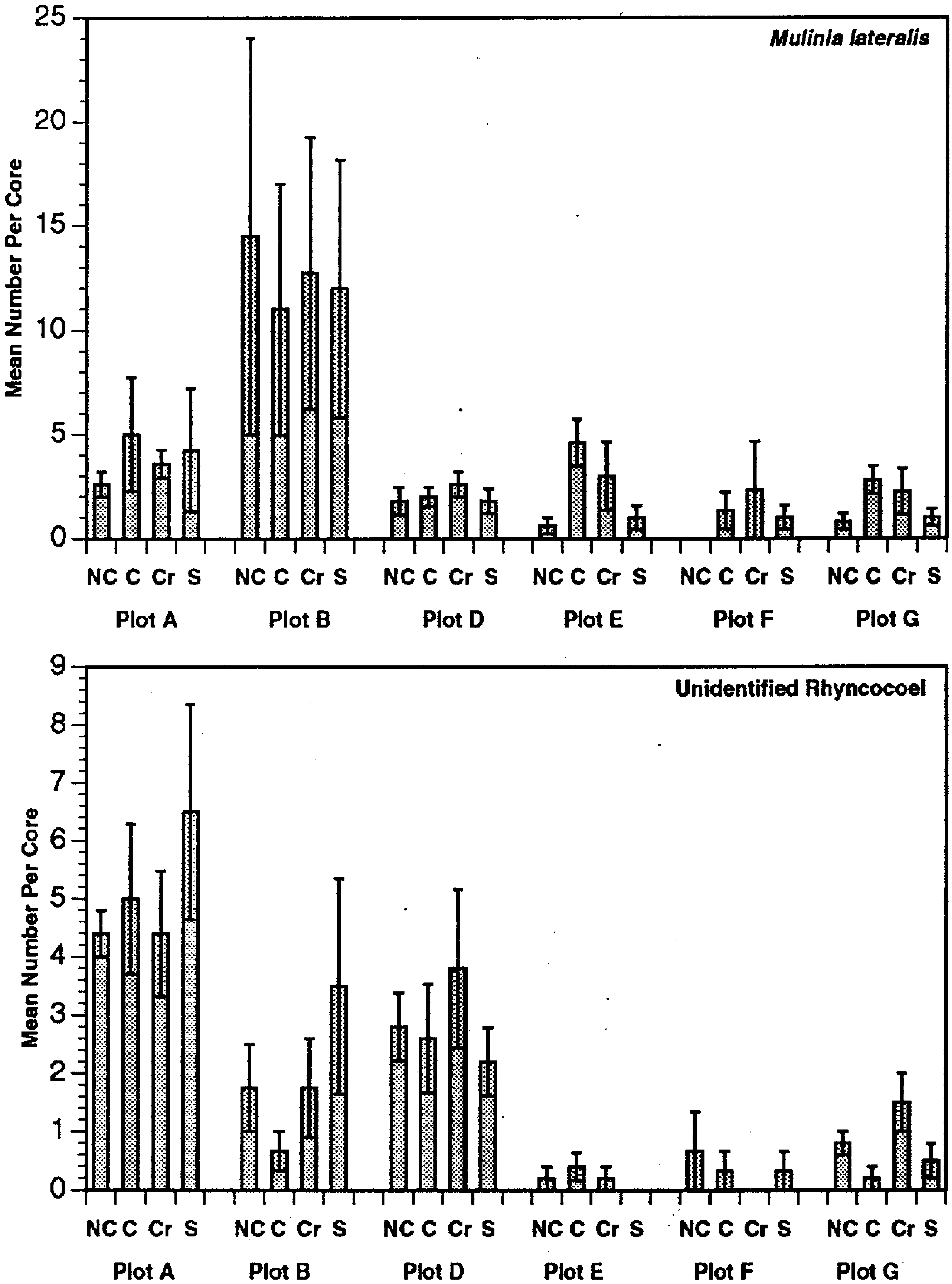

Figure 25: Abundance (number per $0.031m^2$) of the mollusc *Mulinia lateralis* and an unidentified rhyncocoel from different treatments at experimental (B and F) and control plots in Galveston Bay for fall 1992. Mean values are shown (See Table 1 for Ns), error bars represent ± 1 SE. Treatments included No cage (NC), Control Cage (C), Crab Cage (Cr), and Shrimp cage (S).

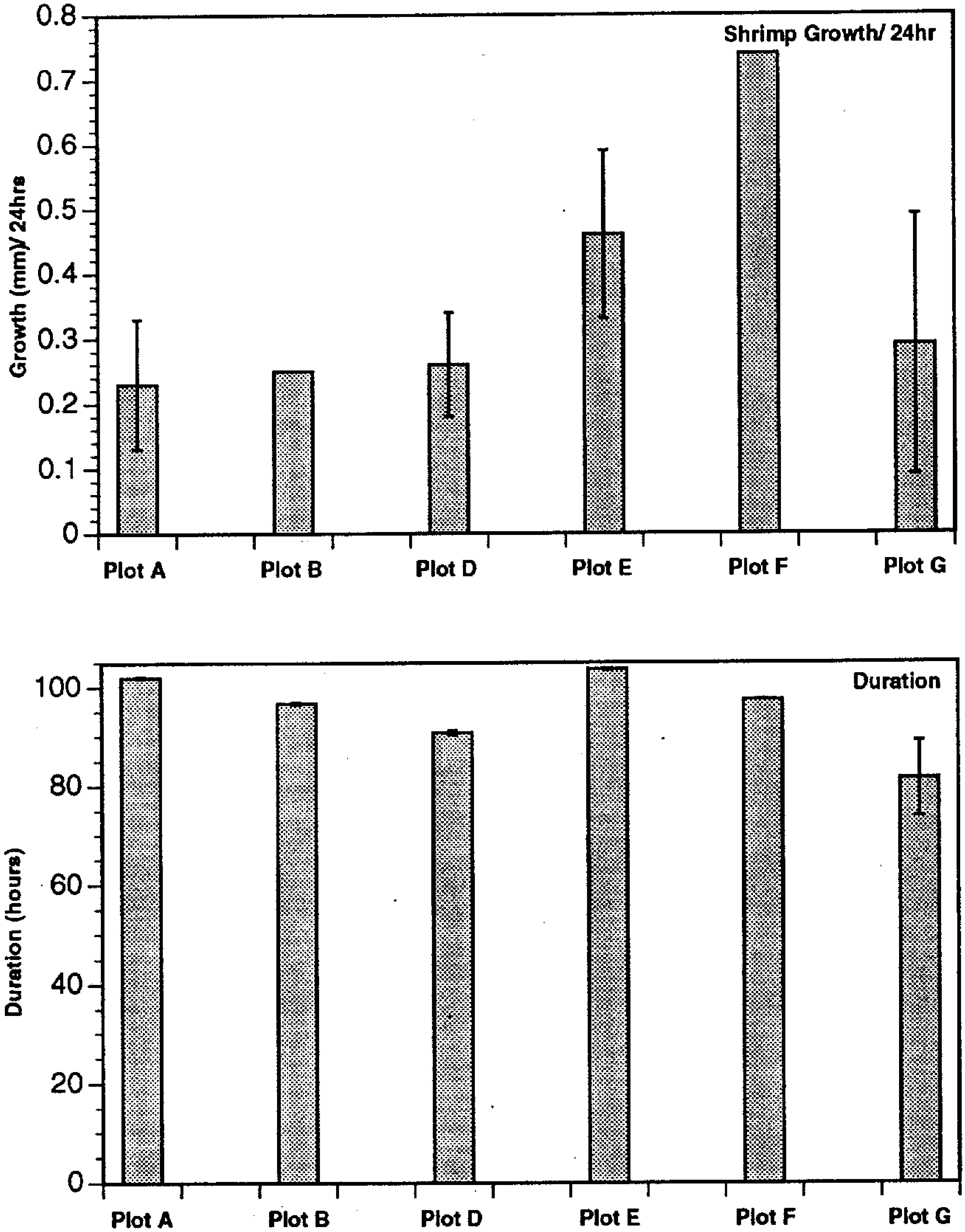

Figure 26: Mean white shrimp growth (mm per 24 hr) and mean experimental duration at experimental (B and F) and control plots in Galveston Bay during fall 1992. Error bars represent ± 1 SE.

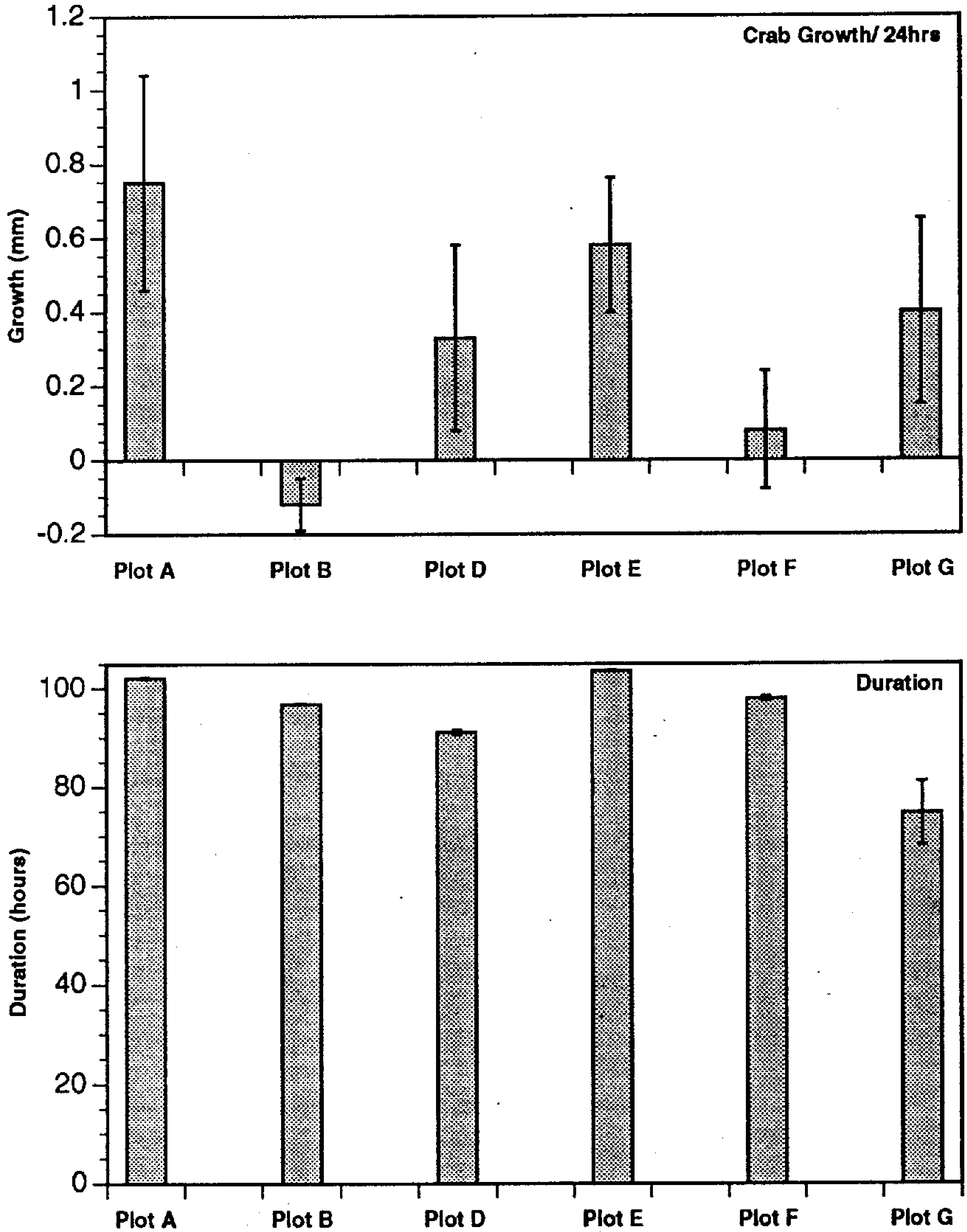

Figure 27: Mean crab growth (mm per 24 hr) and mean experimental duration at experimental (B and F) and control plots in Galveston Bay during fall 1992. Error bars represent ± 1 SE.

List of Tables

Table 1. Number of successful retrievals (observations) for different caging treatments at each Plot for spring and fall experiments.

Spring

Plot	Brown Shrimp	Atlantic Croaker	Control Cage	Control Core	Sum
A	3	0	4	4	11
B	5	0	3	5	13
D	5	0	6	7	18
E	5	0	5	7	17
F	4	0	4	7	15
G	5	0	4	5	14
Sum	27	0	26	35	88

Fall

Plot	White Shrimp	Blue Crab	Control Cage	Control Core	Sum
A	4	5	4	5	18
B	4	4	3	4	15
D	5	5	5	5	20
E	3	5	5	5	18
F	3	3	3	3	12
G	4	4	5	5	18
Sum	23	26	25	27	101

Table 2. Mean abundance values from all plots for the three experimental treatments in spring of 1992. The mean number of benthic infauna with standard error is shown for 307.7-sq-cm cores taken following the experiment. Natural cores were uncaged, Control cages contained no predators, and Shrimp cages contained juvenile brown shrimp. Polychaetes marked with an asterisk were considered available to predators.

		Natural (N=35)		Control cage (N=26)		Shrimp cage (N=27)		Total
Species	Family	Mean	SE	Mean	SE	Mean	SE	Abundance
Total Infauna		**27.26**	**4.23**	**36.50**	**6.54**	**31.41**	**4.70**	**2751**
Total Annelids (All Polychaetes)		18.49	2.70	18.35	2.23	20.52	2.68	1678
Mediomastus spp.	Capitellidae	8.40	2.03	7.50	1.52	6.11	1.36	654
* *Streblospio benedicti*	Spionidae	3.83	0.84	5.00	1.00	4.96	0.94	398
* *Polydora socialis*	Spionidae	1.89	1.22	0.46	0.35	3.07	1.50	161
* *Paraprionospio pinnata*	Spionidae	0.97	0.36	1.42	0.61	1.04	0.48	99
* *Polydora cornuta*	Spionidae	0.77	0.38	0.46	0.39	2.04	1.10	94
* *Nereis succinea*	Nereidae	0.54	0.18	0.62	0.43	1.11	0.62	65
Parandalia sp.A	Pilargidae	0.57	0.17	0.73	0.33	0.81	0.42	61
Glycinde solitaria	Goniadidae	0.20	0.11	0.46	0.20	0.26	0.14	26
Unidentified	Maldanidae	0.17	0.08	0.27	0.10	0.11	0.06	16
* *Hobsonia florida*	Ampharetidae	0.09	0.05	0.23	0.19	0.19	0.08	14
Capitella capitata	Capitellidae	0.14	0.10	0.12	0.08	0.15	0.09	12
Eteone lactea	Phyllodocidae	0.09	0.06	0.23	0.13	0.11	0.11	12
Sigambra bassi	Pilargidae	0.09	0.05	0.08	0.05	0.07	0.05	7
Sigambra tentaculata	Pilargidae	0.03	0.03	0.12	0.06	0.11	0.08	7
Lepidasthenia varius	Polynoidae	0.06	0.04	0.12	0.08	0.07	0.05	7
* *Loimia sp.A*	Terebellidae	0.06	0.04	0.00	0.00	0.19	0.15	7
* *Magelona sp.H*	Magelonidae	0.03	0.03	0.15	0.12	0.04	0.04	6
Lumbrineris verrilli	Lumbrineridae	0.09	0.06	0.04	0.04	0.00	0.00	4
* *Leitoscoloplos spp.*	Orbiniidae	0.06	0.04	0.08	0.05	0.00	0.00	4
* *Prionospio perkinsi*	Spionidae	0.06	0.04	0.04	0.04	0.04	0.04	4
* *Paramphinome sp.B*	Amphinomidae	0.09	0.05	0.00	0.00	0.00	0.00	3
Spiochaetopterus oculatus	Chaetopteridae	0.06	0.06	0.00	0.00	0.00	0.00	2

Table 2 (continued)

Species	Family	Natural (N=35) Mean	SE	Control cage (N=26) Mean	SE	Shrimp cage (N=27) Mean	SE	Total Abundance
* *Nereis spp.*	Nereidae	0.00	0.00	0.08	0.05	0.00	0.00	2
Aricidea catherinae	Paraonidae	0.06	0.04	0.00	0.00	0.00	0.00	2
Pectinaria gouldii	Pectinariidae	0.00	0.00	0.08	0.05	0.00	0.00	2
* Unidentified	Phyllodocidae	0.06	0.04	0.00	0.00	0.00	0.00	2
Unidentified	Ampharetidae	0.00	0.00	0.04	0.04	0.00	0.00	1
Heteromastus filiformis	Capitellidae	0.03	0.03	0.00	0.00	0.00	0.00	1
* *Podarkeopsis levifuscina*	Hesionidae	0.00	0.00	0.04	0.04	0.00	0.00	1
Diopatra cuprea	Onuphidae	0.00	0.00	0.00	0.00	0.04	0.04	1
Sthenelais sp.A	Sigalionidae	0.03	0.03	0.00	0.00	0.00	0.00	1
* *Polydora spp.*	Spionidae	0.03	0.03	0.00	0.00	0.00	0.00	1
* *Spiophanes bombyx*	Spionidae	0.03	0.03	0.00	0.00	0.00	0.00	1
Total Crustaceans		1.57	0.39	5.50	1.42	3.22	0.62	285
Total Amphipods		0.34	0.12	2.73	0.86	1.44	0.37	122
Melita spp.	Melitidae	0.23	0.08	0.69	0.21	0.74	0.29	46
Microprotopus spp.	Isaeidae	0.00	0.00	0.50	0.32	0.11	0.08	16
Monoculodes spp.	Oedicerotidae	0.00	0.00	0.35	0.17	0.11	0.08	12
Batea catharinensis	Bateidae	0.00	0.00	0.35	0.27	0.07	0.07	11
Parametopella cypris	Stenothoidae	0.03	0.03	0.31	0.21	0.04	0.04	10
Corophium lacustre	Corophiidae	0.06	0.06	0.00	0.00	0.15	0.09	6
Unidentified	Melitidae	0.00	0.00	0.08	0.05	0.11	0.06	5
Grandidierella bonnieroides	Aoridae	0.00	0.00	0.08	0.05	0.04	0.04	3
Unidentified	Corophiidae	0.03	0.03	0.04	0.04	0.00	0.00	2
Corophium sp.O	Corophiidae	0.00	0.00	0.08	0.05	0.00	0.00	2
Unidentified	Oedicerotidae	0.00	0.00	0.04	0.04	0.04	0.04	2
Parametopella spp.	Stenothoidae	0.00	0.00	0.04	0.04	0.04	0.04	2
Microdeutopus spp.	Aoridae	0.00	0.00	0.04	0.04	0.00	0.00	1
Batea spp.	Bateidae	0.00	0.00	0.04	0.04	0.00	0.00	1
Unidentified	Caprellidae	0.00	0.00	0.04	0.04	0.00	0.00	1

Table 2 (continued)

Species	Family	Natural (N=35) Mean	SE	Control cage (N=26) Mean	SE	Shrimp cage (N=27) Mean	SE	Total Abundance
Gammarus mucronatus	Gammaridae	0.00	0.00	0.04	0.04	0.00	0.00	1
Unidentified	Stenothoidae	0.00	0.00	0.04	0.04	0.00	0.00	1
Total Decapods		1.03	0.32	2.46	0.60	1.63	0.39	144
Unidentified	Portunidae	0.06	0.04	0.73	0.27	0.33	0.18	30
Pinnixa spp.	Pinnotheridae	0.43	0.23	0.19	0.12	0.07	0.05	22
Palaemonetes spp.	Palaemonidae	0.03	0.03	0.31	0.14	0.26	0.11	16
Unidentified	Xanthidae	0.11	0.07	0.12	0.08	0.22	0.10	13
Rhithropanopeus harrisii	Xanthidae	0.14	0.07	0.15	0.15	0.07	0.07	11
Ogyrides alphaerostris	Ogyrididae	0.09	0.05	0.23	0.08	0.00	0.00	9
Unidentified	Suborder Natantia	0.06	0.04	0.08	0.05	0.11	0.06	7
Latreutes parvulus	Hippolytidae	0.00	0.00	0.15	0.11	0.11	0.11	7
Unidentified	Infraorder Brachyura	0.03	0.03	0.19	0.10	0.04	0.04	7
Callinectes spp.	Portunidae	0.00	0.00	0.04	0.04	0.15	0.15	5
Unidentified	Majidae	0.00	0.00	0.12	0.08	0.04	0.04	4
Unidentified	Palaemonidae	0.00	0.00	0.00	0.00	0.11	0.08	3
Unidentified	Pinnotheridae	0.03	0.03	0.04	0.04	0.04	0.04	3
Callinectes similis	Portunidae	0.00	0.00	0.04	0.04	0.04	0.04	2
Latreutes spp.	Hippolytidae	0.00	0.00	0.04	0.04	0.00	0.00	1
Penaeus spp.	Penaeidae	0.00	0.00	0.00	0.00	0.04	0.04	1
Callianassa sp.J	Callianassidae	0.03	0.03	0.00	0.00	0.00	0.00	1
Unidentified	Callianassidae	0.00	0.00	0.04	0.04	0.00	0.00	1
Upogebia affinis	Upogebiidae	0.03	0.03	0.00	0.00	0.00	0.00	1
Other Crustaceans		0.20	0.09	0.31	0.11	0.15	0.07	19
Oxyurostylis spp.	Order Cumacea	0.11	0.07	0.15	0.09	0.04	0.04	9
Edotea sp.B	Order Isopoda	0.03	0.03	0.04	0.04	0.07	0.05	4
Cyclaspis varians	Order Cumacea	0.03	0.03	0.04	0.04	0.00	0.00	2
Mysidopsis bahia	Order Mysidacea	0.00	0.00	0.08	0.05	0.00	0.00	2
Xenanthura brevitelson	Order Isopoda	0.00	0.00	0.00	0.00	0.04	0.04	1

Table 2 (continued)

Species	Family	Natural (N=35) Mean	Natural (N=35) SE	Control cage (N=26) Mean	Control cage (N=26) SE	Shrimp cage (N=27) Mean	Shrimp cage (N=27) SE	Total Abundance
Unidentified	Order Mysidacea	0.03	0.03	0.00	0.00	0.00	0.00	1
Total Molluscs		2.40	0.39	4.27	0.90	2.48	0.51	262
Mulinia lateralis	Mactridae	0.63	0.22	1.77	0.72	1.19	0.43	100
Tellina versicolor	Tellinidae	0.63	0.20	0.73	0.29	0.70	0.29	60
Littoridinops palustris	Hydrobiidae	0.46	0.18	0.54	0.43	0.04	0.04	31
Polinices duplicatus	Naticidae	0.20	0.10	0.46	0.24	0.19	0.09	24
Cyrtopleura costata	Pholadidae	0.23	0.18	0.08	0.05	0.30	0.30	18
Unidentified	Class Pelecypoda	0.03	0.03	0.23	0.16	0.00	0.00	7
Odostomia weberi	Pyramidellidae	0.09	0.06	0.04	0.04	0.04	0.04	5
Nassarius acutus	Nassariidae	0.06	0.04	0.08	0.08	0.00	0.00	4
Sphaerium spp.	Sphaeriidae	0.00	0.00	0.15	0.15	0.00	0.00	4
Unidentified	Order Nudibranchia	0.03	0.03	0.04	0.04	0.00	0.00	2
Brachidontes exustus	Mytilidae	0.00	0.00	0.04	0.04	0.04	0.04	2
Unidentified	Class Gastropoda	0.03	0.03	0.00	0.00	0.00	0.00	1
Caecum sp.A	Caecidae	0.03	0.03	0.00	0.00	0.00	0.00	1
Acteocina canaliculata	Scaphandridae	0.00	0.00	0.04	0.04	0.00	0.00	1
Terebra dislocata	Terebridae	0.00	0.00	0.04	0.04	0.00	0.00	1
Diplodonta semiaspera	Ungulinidae	0.00	0.00	0.04	0.04	0.00	0.00	1
Total Others		4.80	1.62	8.38	3.95	5.19	2.67	526
Balanoglossus spp.	Class Enteropneusta	2.37	1.33	5.19	3.47	3.93	2.54	324
Unidentified	Phylum Rhynchocoel:	1.66	0.35	2.04	0.48	1.00	0.23	138
Balanoglossus aurantiacus	Class Enteropneusta	0.29	0.23	0.38	0.31	0.07	0.07	22
Unidentified	Class Turbellaria	0.29	0.20	0.19	0.10	0.11	0.06	18
Unidentified	Phylum Cnidaria	0.03	0.03	0.38	0.38	0.00	0.00	11
Unidentified	Order Actiniaria	0.14	0.08	0.08	0.05	0.07	0.05	9
Phoronis spp.	Phylum Phoronida	0.00	0.00	0.12	0.06	0.00	0.00	3
Unidentified	Phylum Echiura	0.03	0.03	0.00	0.00	0.00	0.00	1

Table 3. Analysis of variance results for the spring caging experiment in Galveston Bay. Log-transformed density and biomass of dominant taxa were used as observations. Treatment had three levels; no cage, control cage, and shrimp (brown shrimp) cage. A priori contrasts of the interaction term were used to compare values in shrimp cages and control cages.

Abundance

Total Infauna

Source	df	SS	MS	F	P
Plot	5	4.900	0.980	20.268	0.000
Treatment	2	0.227	0.114	2.350	0.103
Treatment * Plot	10	0.656	0.066	1.357	0.218
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.005	0.005	0.098	0.755
In Exp Plots	1	0.020	0.020	0.423	0.518
Residual	70	3.384	0.048		

Annelids

Source	df	SS	MS	F	P
Plot	5	3.510	0.702	7.228	0.000
Treatment	2	0.510	0.255	2.626	0.080
Treatment * Plot	10	0.829	0.083	0.854	0.579
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.083	0.083	0.854	0.359
In Exp Plots	1	0.134	0.134	1.376	0.244
Residual	70	6.795	0.097		

Available polychaetes

Source	df	SS	MS	F	P
Plot	5	4.930	0.986	13.097	0.000
Treatment	2	0.075	0.037	0.495	0.612
Treatment * Plot	10	0.951	0.095	1.263	0.268
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.004	0.004	0.053	0.819
In Exp Plots	1	0.000	0.000	0.002	0.966
Residual	70	5.269	0.075		

Table 3 (continued)

Mediomastus spp.

Source	df	SS	MS	F	P
Plot	5	18.163	3.633	59.231	0.000
Treatment	2	0.042	0.021	0.343	0.711
Treatment * Plot	10	0.780	0.078	1.272	0.263
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.014	0.014	0.230	0.633
In Exp Plots	1	1.164	1.164	18.986	0.000
Residual	70	4.293	0.061		

Streblospio benedicti

Source	df	SS	MS	F	P
Plot	5	5.639	1.128	11.313	0.000
Treatment	2	0.258	0.129	1.293	0.281
Treatment * Plot	10	0.886	0.089	0.888	0.548
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.075	0.075	0.755	0.388
In Exp Plots	1	0.374	0.374	3.748	0.057
Residual	70	6.978	0.100		

Crustaceans

Source	df	SS	MS	F	P
Plot	5	4.456	0.891	12.682	0.000
Treatment	2	1.759	0.880	12.517	0.000
Treatment * Plot	10	0.629	0.063	0.895	0.543
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.084	0.084	1.196	0.278
In Exp Plots	1	0.062	0.062	0.877	0.352
Residual	70	4.919	0.070		

Amphipods

Source	df	SS	MS	F	P
Plot	5	1.810	0.362	6.335	0.000
Treatment	2	1.714	0.857	14.993	0.000
Treatment * Plot	10	1.214	0.121	2.124	0.034
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.103	0.103	1.794	0.185
In Exp Plots	1	0.043	0.043	0.753	0.389
Residual	70	4.000	0.057		

Table 3 (continued)

Decapods

Source	df	SS	MS	F	P
Plot	5	3.003	0.601	9.845	0.000
Treatment	2	0.503	0.252	4.124	0.020
Treatment * Plot	10	0.355	0.035	0.582	0.824
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.124	0.124	2.029	0.159
In Exp Plots	1	0.049	0.049	0.797	0.375
Residual	70	4.270	0.061		

Molluscs

Source	df	SS	MS	F	P
Plot	5	3.703	0.741	8.731	0.000
Treatment	2	0.543	0.272	3.201	0.047
Treatment * Plot	10	0.743	0.074	0.876	0.560
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.373	0.373	4.401	0.040
In Exp Plots	1	0.034	0.034	0.400	0.529
Residual	70	5.938	0.085		

Mulinia lateralis

Source	df	SS	MS	F	P
Plot	5	4.767	0.953	22.160	0.000
Treatment	2	0.256	0.128	2.972	0.058
Treatment * Plot	10	0.702	0.070	1.631	0.116
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.000	0.000	0.000	0.988
In Exp Plots	1	0.099	0.099	2.310	0.133
Residual	70	3.011	0.043		

Biomass

Total Infauna

Source	df	SS	MS	F	P
Plot	5	0.086	0.017	7.123	0.000
Treatment	2	0.010	0.005	1.991	0.144
Treatment * Plot	10	0.017	0.002	0.708	0.714
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.000	0.000	0.096	0.758
In Exp Plots	1	0.005	0.005	1.889	0.174
Residual	70	0.170	0.002		

Table 3 (continued)

Annelids

Source	df	SS	MS	F	P
Plot	5	0.018	0.004	12.576	0.000
Treatment	2	0.001	0.000	1.334	0.270
Treatment * Plot	10	0.002	0.000	0.621	0.791
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.000	0.000	0.529	0.469
In Exp Plots	1	0.000	0.000	0.453	0.503
Residual	70	0.020	0.000		

Crustaceans

Source	df	SS	MS	F	P
Plot	5	0.012	0.002	3.097	0.014
Treatment	2	0.004	0.002	2.613	0.081
Treatment * Plot	10	0.013	0.001	1.762	0.084
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.000	0.000	0.196	0.660
In Exp Plots	1	0.010	0.010	13.602	0.000
Residual	70	0.053	0.001		

Molluscs

Source	df	SS	MS	F	P
Plot	5	0.043	0.009	4.592	0.001
Treatment	2	0.000	0.000	0.124	0.884
Treatment * Plot	10	0.013	0.001	0.665	0.753
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.000	0.000	0.076	0.784
In Exp Plots	1	0.003	0.003	1.820	0.182
Residual	70	0.132	0.002		

Table 4. Mean abundance values from all plots for the four experimental treatments in fall of 1992. The mean number of benthic infauna with standard error is shown for 307.7-sq-cm cores/cages taken following the experiment. Natural cores were uncaged, Control cages contained no predators, Crab cages contained juvenile blue crabs, and Shrimp cages contained juvenile white shrimp. Polychaetes marked with an asterisk were considered available to predators.

Species	Family	Natural (N=27)		Control cage (N=25)		Crab cage (n=26)		Shrimp cage (N=23)		Total
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Abundance
Total Infauna		27.48	3.82	31.48	3.57	33.38	3.08	32.00	3.85	3133
Total Annelids		18.56	2.19	18.72	2.61	19.69	2.33	20.22	2.59	1946
Polychaetes		18.44	2.17	18.52	2.53	19.54	2.34	20.17	2.57	1933
Mediomastus spp.	Capitellidae	7.33	1.47	6.52	1.33	8.35	2.12	7.30	1.77	746
Glycinde solitaria	Goniadidae	2.30	0.48	2.48	0.40	2.65	0.45	2.87	0.48	259
* *Paraprionospio pinnata*	Spionidae	2.89	0.76	1.88	0.53	2.50	0.75	2.52	0.80	248
Parandalia sp.A	Pilargidae	1.41	0.42	1.44	0.40	1.19	0.51	0.57	0.25	118
* *Nereis succinea*	Nereidae	0.56	0.34	0.80	0.53	0.62	0.40	1.26	0.68	80
Unidentified	Maldanidae	0.41	0.15	0.56	0.23	0.15	0.09	0.61	0.21	43
Sigambra spp.	Pilargidae	0.52	0.21	0.28	0.14	0.23	0.10	0.52	0.14	39
* *Polydora socialis*	Spionidae	0.30	0.12	0.52	0.26	0.15	0.07	0.39	0.26	34
* *Magelona spp.*	Magelonidae	0.37	0.23	0.28	0.18	0.35	0.17	0.30	0.19	33
* *Nereis spp.*	Nereidae	0.22	0.12	0.52	0.29	0.38	0.16	0.09	0.06	31
* *Sthenelais sp.A*	Sigalionidae	0.07	0.05	0.44	0.18	0.46	0.17	0.22	0.09	30
* *Nereis micromma*	Nereidae	0.33	0.17	0.28	0.15	0.15	0.11	0.39	0.23	29
* *Streblospio benedicti*	Spionidae	0.04	0.04	0.44	0.25	0.19	0.08	0.48	0.21	28
Spiochaetopterus oculatus	Chaetopteridae	0.22	0.10	0.24	0.10	0.35	0.12	0.17	0.14	25
* *Leitoscoloplos spp.*	Orbiniidae	0.07	0.05	0.20	0.16	0.12	0.06	0.52	0.22	22
Owenia sp.A	Oweniidae	0.19	0.09	0.20	0.14	0.12	0.08	0.26	0.16	19
Unidentified	Onuphidae	0.04	0.04	0.20	0.08	0.15	0.09	0.30	0.18	17
Diopatra cuprea	Onuphidae	0.11	0.08	0.20	0.08	0.08	0.05	0.22	0.22	15
Cossura soyeri	Cossuridae	0.07	0.05	0.12	0.07	0.08	0.05	0.13	0.10	10
* *Paramphinome sp.B*	Amphinomidae	0.11	0.08	0.00	0.00	0.15	0.15	0.04	0.04	8
* *Podarkeopsis levifuscina*	Hesionidae	0.15	0.09	0.00	0.00	0.04	0.04	0.09	0.06	7
Lumbrineris spp.	Lumbrineridae	0.07	0.05	0.08	0.06	0.08	0.05	0.00	0.00	6
Diopatra spp.	Onuphidae	0.04	0.04	0.00	0.00	0.08	0.05	0.13	0.10	6
Galathowenia oculata	Oweniidae	0.04	0.04	0.08	0.06	0.04	0.04	0.04	0.04	5

Table 4 (continued)

Species	Family	Natural (N=27) Mean	Natural (N=27) SE	Control cage (N=25) Mean	Control cage (N=25) SE	Crab cage (n=26) Mean	Crab cage (n=26) SE	Shrimp cage (N=23) Mean	Shrimp cage (N=23) SE	Total Abundance
* Unidentified	Phyllodocidae	0.07	0.07	0.00	0.00	0.12	0.06	0.00	0.00	5
Aricidea philbinae	Paraonidae	0.00	0.00	0.04	0.04	0.04	0.04	0.09	0.06	4
Pectinaria gouldii	Pectinariidae	0.04	0.04	0.00	0.00	0.08	0.05	0.04	0.04	4
Euclymene sp.B	Maldanidae	0.04	0.04	0.00	0.00	0.00	0.00	0.09	0.09	3
* *Armandia maculata*	Opheliidae	0.00	0.00	0.00	0.00	0.08	0.05	0.04	0.04	3
* *Prionospio perkinsi*	Spionidae	0.04	0.04	0.04	0.04	0.00	0.00	0.04	0.04	3
Capitella capitata	Capitellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.06	2
Aricidea spp.	Paraonidae	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.04	2
* Unidentified	Terebellidae	0.04	0.04	0.00	0.00	0.04	0.04	0.00	0.00	2
* *Sabellides sp.A*	Ampharetidae	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	1
Chaetopterus spp.	Chaetopteridae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1
* Unidentified	Cirratulidae	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	1
* *Tharyx Cf. annulosus*	Cirratulidae	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	1
Unidentified	Orbiniidae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1
* Unidentified	Paraonidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
Amphictene spp.	Pectinariidae	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	1
Anaitides spp.	Phyllodocidae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1
Phyllodoce arenae	Phyllodocidae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1
Ancistrosyllis jonesi	Pilargidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
Lepidasthenia varius	Polynoidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
* Unidentified	Sabellidae	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	1
* *Polydora cornuta*	Spionidae	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	1
* *Prionospio spp.*	Spionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
* *Scolelepis texana*	Spionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
* Unidentified	Spionidae	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	1
Oligochaetes		0.11	0.11	0.20	0.13	0.15	0.09	0.04	0.04	13
Total Crustaceans		2.04	0.77	4.56	0.71	3.92	0.71	3.65	0.91	355
Total Amphipods		0.37	0.09	1.08	0.18	0.96	0.17	1.65	0.78	100
Corophium spp.	Corophiidae	0.04	0.04	0.16	0.07	0.00	0.00	0.83	0.61	24
Ampelisca spp.	Ampeliscidae	0.15	0.07	0.40	0.14	0.27	0.12	0.09	0.06	23

Table 4 (continued)

Species	Family	Natural (N=27) Mean	SE	Control cage (N=25) Mean	SE	Crab cage (n=26) Mean	SE	Shrimp cage (N=23) Mean	SE	Total Abundance
Gitanopsis spp.	Amphilochidae	0.04	0.04	0.20	0.08	0.23	0.10	0.13	0.07	15
Batea catharinensis	Bateidae	0.00	0.00	0.20	0.10	0.19	0.10	0.04	0.04	11
Unidentified	Corophiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.18	7
Unidentified	Bateidae	0.00	0.00	0.08	0.06	0.08	0.05	0.04	0.04	5
Unidentified	Order Amphipoda	0.07	0.05	0.04	0.04	0.00	0.00	0.04	0.04	4
Microprotopus spp.	Isaeidae	0.00	0.00	0.00	0.00	0.04	0.04	0.09	0.06	3
Grandidierella bonnieroides	Aoridae	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04	2
Melita spp.	Melitidae	0.04	0.04	0.00	0.00	0.04	0.04	0.00	0.00	2
Unidentified	Ampeliscidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
Unidentified	Aoridae	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	1
Unidentified	Caprellidae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1
Unidentified	Phoxocephalidae	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	1
Total Decapods		0.67	0.23	1.08	0.25	1.08	0.17	1.30	0.32	103
Unidentified	Portunidae	0.11	0.11	0.44	0.15	0.27	.0.10	0.30	0.13	28
Unidentified	Suborder Natantia	0.19	0.08	0.08	0.06	0.08	0.05	0.22	0.11	14
Unidentified	InfraorderBrachyura	0.19	0.11	0.08	0.08	0.08	0.05	0.09	0.06	11
Latreutes parvulus	Hippolytidae	0.00	0.00	0.12	0.07	0.12	0.06	0.13	0.07	9
Callinectes spp.	Portunidae	0.00	0.00	0.16	0.09	0.12	0.06	0.04	0.04	8
Unidentified	Suborder Reptantia	0.04	0.04	0.00	0.00	0.15	0.07	0.04	0.04	6
Unidentified	Goneplacidae	0.04	0.04	0.00	0.00	0.04	0.04	0.17	0.14	6
Ogyrides alphaerostris	Ogyrididae	0.04	0.04	0.08	0.06	0.04	0.04	0.04	0.04	5
Panoplax depressa	Goneplacidae	0.00	0.00	0.04	0.04	0.08	0.05	0.09	0.06	5
Unidentified	Hippolytidae	0.00	0.00	0.00	0.00	0.08	0.05	0.04	0.04	3
Pinnixa spp.	Pinnotheridae	0.04	0.04	0.00	0.00	0.04	0.04	0.00	0.00	2
Upogebia affinis	Upogebiidae	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.04	2
Lysmata spp.	Hippolytidae	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	1
Penaeus setiferus	Penaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
Chasmocarcinus mississippiensi	Goneplacidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
Unidentified	Paguridae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1

Table 4 (continued)

Species	Family	Natural (N=27)		Control cage (N=25)		Crab cage (n=26)		Shrimp cage (N=23)		Total
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Abundance
Other Crustaceans		1.00	0.56	2.40	0.55	1.88	0.73	0.70	0.25	152
Cyclaspis varians	Bodotriidae	0.85	0.49	1.56	0.45	1.58	0.62	0.52	0.20	115
Unidentified	Bodotriidae	0.11	0.08	0.40	0.14	0.12	0.08	0.04	0.04	17
Oxyurostylis spp.	Diastylidae	0.00	0.00	0.28	0.11	0.00	0.00	0.09	0.09	9
Unidentified	Order Cumacea	0.00	0.00	0.12	0.07	0.12	0.06	0.04	0.04	7
Unidentified	Diastylidae	0.00	0.00	0.00	0.00	0.08	0.05	0.00	0.00	2
Unidentified	Hyssuridae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1
Chironomus spp.	Chironomidae	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	1
Total Molluscs		4.93	1.74	6.48	0.98	7.58	1.62	5.52	1.52	619
Mulinia lateralis	Mactridae	3.22	1.57	4.16	0.96	4.35	1.22	3.65	1.37	388
Texadina barretti	Hydrobiidae	0.41	0.25	0.56	0.23	1.42	0.82	0.13	0.07	65
Petricola pholadiformis	Petricolidae	0.52	0.20	0.56	0.42	0.73	0.44	0.70	0.34	63
Abra aequalis	Semelidae	0.11	0.08	0.20	0.12	0.38	0.17	0.43	0.29	28
Unidentified	Class Pelecypoda	0.11	0.06	0.32	0.15	0.35	0.27	0.04	0.04	21
Anadara transversa	Arcidae	0.00	0.00	0.12	0.07	0.04	0.04	0.22	0.11	9
Hiatella arctica	Hiatellidae	0.19	0.19	0.00	0.00	0.00	0.00	0.13	0.10	8
Nassarius acutus	Nassariidae	0.11	0.08	0.08	0.06	0.04	0.04	0.00	0.00	6
Caecum johnsoni	Caecidae	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	5
Unidentified	Class Gastropoda	0.00	0.00	0.00	0.00	0.08	0.05	0.09	0.06	4
Macoma mitchelli	Tellinidae	0.04	0.04	0.04	0.04	0.08	0.05	0.00	0.00	4
Polinices duplicatus	Naticidae	0.00	0.00	0.08	0.06	0.00	0.00	0.04	0.04	3
Tellina texana	Tellinidae	0.07	0.07	0.00	0.00	0.04	0.04	0.00	0.00	3
Crepidula spp.	Crepidulidae	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	2
Acteocina canaliculata	Scaphandridae	0.00	0.00	0.04	0.04	0.00	0.00	0.04	0.04	2
Musculus lateralis	Mytilidae	0.00	0.00	0.04	0.04	0.04	0.04	0.00	0.00	2
Tellina versicolor	Tellinidae	0.00	0.00	0.04	0.04	0.04	0.04	0.00	0.00	2
Anachis obesa	Columbellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
Natica pusilla	Naticidae	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	1
Macoma pulleyi	Tellinidae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1
Dosinia discus	Veneridae	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1

Table 4 (continued)

Species	Family	Natural (N=27) Mean	SE	Control cage (N=25) Mean	SE	Crab cage (n=26) Mean	SE	Shrimp cage (N=23) Mean	SE	Total Abundance
Total Others		1.96	0.36	1.72	0.46	2.19	0.48	2.61	0.69	213
Unidentified	Phylum Rhynchocoela	1.85	0.34	1.56	0.44	2.12	0.47	2.35	0.64	198
Phoronis spp.	Phylum Phoronida	0.04	0.04	0.04	0.04	0.04	0.04	0.17	0.08	7
Unidentified	Order Actiniaria	0.04	0.04	0.04	0.04	0.00	0.00	0.00	0.00	2
Mellita spp.	Mellitidae	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.00	2
Unidentified	Class Ophiuroidea	0.04	0.04	0.00	0.00	0.04	0.04	0.00	0.00	2
Branchiostoma floridae	Branchiostomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1
Balanoglossus spp.	Class Enteropneusta	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1

Table 5. Analysis of variance results for the fall caging experiment in Galveston Bay. Log-transformed density and biomass of dominant taxa were used as observations. Treatment had four levels; no cage, control cage, shrimp cage, and crab cage. A priori contrasts of the interaction term were used to compare values in shrimp cages and control cages.

Abundance

Total Infauna

Source	df	SS	MS	F	P
Plot	5	2.675	0.535	15.658	0.000
Treatment	3	0.183	0.061	1.789	0.156
Treatment * Plot	15	0.452	0.030	0.882	0.587
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.022	0.022	0.645	0.424
In Exp Plots	1	0.027	0.027	0.777	0.381
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.001	0.001	0.020	0.888
In Exp Plots	1	0.015	0.015	0.439	0.510
Residual	77	2.631	0.034		

Annelids

Source	df	SS	MS	F	P
Plot	5	3.277	0.655	15.655	0.000
Treatment	3	0.066	0.022	0.522	0.669
Treatment * Plot	15	0.508	0.034	0.808	0.665
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.013	0.013	0.306	0.582
In Exp Plots	1	0.040	0.040	0.947	0.334
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.002	0.002	0.060	0.808
In Exp Plots	1	0.055	0.055	1.309	0.256
Residual	77	3.224	0.042		

Table 5 (continued)

Available polychaetes

Source	df	SS	MS	F	P
Plot	5	10.057	2.011	22.602	0.000
Treatment	3	0.146	0.049	0.546	0.652
Treatment * Plot	15	0.616	0.041	0.461	0.953
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.013	0.013	0.142	0.707
In Exp Plots	1	0.063	0.063	0.710	0.402
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.001	0.001	0.017	0.898
In Exp Plots	1	0.000	0.000	0.000	0.990
Residual	77	6.853	0.089		

Mediomastus spp.

Source	df	SS	MS	F	P
Plot	5	10.888	2.178	24.811	0.000
Treatment	3	0.054	0.018	0.203	0.894
Treatment * Plot	15	1.281	0.085	0.973	0.491
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.022	0.022	0.256	0.615
In Exp Plots	1	0.011	0.011	0.130	0.720
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.008	0.008	0.094	0.760
In Exp Plots	1	0.032	0.032	0.366	0.547
Residual	77	6.758	0.088		

Glycinda spp.

Source	df	SS	MS	F	P
Plot	5	2.178	0.436	6.730	0.000
Treatment	3	0.128	0.043	0.659	0.580
Treatment * Plot	15	0.992	0.066	1.022	0.442
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.036	0.036	0.550	0.461
In Exp Plots	1	0.009	0.009	0.135	0.714
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.002	0.002	0.027	0.870
In Exp Plots	1	0.000	0.000	0.000	0.994
Residual	77	4.983	0.065		

Table 5 (continued)

Paraprionospio pinnata

Source	df	SS	MS	F	P
Plot	5	9.760	1.952	35.518	0.000
Treatment	3	0.065	0.022	0.394	0.758
Treatment * Plot	15	0.349	0.023	0.423	0.968
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.006	0.006	0.108	0.743
In Exp Plots	1	0.019	0.019	0.349	0.557
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.000	0.000	0.000	0.994
In Exp Plots	1	0.022	0.022	0.402	0.528
Residual	77	4.232	0.055		

Crustaceans

Source	df	SS	MS	F	P
Plot	5	2.159	0.432	7.437	0.000
Treatment	3	1.394	0.465	8.007	0.000
Treatment * Plot	15	2.161	0.144	2.482	0.005
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.570	0.570	9.812	0.003
In Exp Plots	1	0.144	0.144	2.485	0.119
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.112	0.112	1.927	0.169
In Exp Plots	1	0.054	0.054	0.929	0.338
Residual	77	4.470	0.058		

Amphipods

Source	df	SS	MS	F	P
Plot	5	0.432	0.086	2.238	0.059
Treatment	3	0.416	0.139	3.591	0.017
Treatment * Plot	15	1.219	0.081	2.107	0.018
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.140	0.140	3.623	0.061
In Exp Plots	1	0.202	0.202	5.248	0.025
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.013	0.013	0.331	0.567
In Exp Plots	1	0.000	0.000	0.007	0.932
Residual	77	2.969	0.039		

Table 5 (continued)

Decapods

Source	df	SS	MS	F	P
Plot	5	1.708	0.342	9.457	0.000
Treatment	3	0.276	0.092	2.542	0.062
Treatment * Plot	15	1.038	0.069	1.916	0.034
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.020	0.020	0.552	0.460
In Exp Plots	1	0.055	0.055	1.517	0.222
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.002	0.002	0.069	0.794
In Exp Plots	1	0.024	0.024	0.664	0.418
Residual	77	2.782	0.036		

Molluscs

Source	df	SS	MS	F	P
Plot	5	4.827	0.965	13.853	0.000
Treatment	3	1.027	0.342	4.912	0.004
Treatment * Plot	15	0.939	0.063	0.899	0.569
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.638	0.638	9.158	0.003
In Exp Plots	1	0.000	0.000	0.006	0.937
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.011	0.011	0.155	0.695
In Exp Plots	1	0.004	0.004	0.053	0.819
Residual	77	5.366	0.070		

Mulinia lateralis

Source	df	SS	MS	F	P
Plot	5	4.747	0.949	9.870	0.000
Treatment	3	0.738	0.246	2.557	0.061
Treatment * Plot	15	0.676	0.045	0.468	0.950
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.443	0.443	4.602	0.035
In Exp Plots	1	0.002	0.002	0.020	0.889
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.057	0.057	0.591	0.445
In Exp Plots	1	0.006	0.006	0.067	0.797
Residual	77	7.408	0.096		

Table 5 (continued)

Rhyncocoels

Source	df	SS	MS	F	P
Plot	5	6.142	1.228	32.590	0.000
Treatment	3	0.092	0.031	0.816	0.489
Treatment * Plot	15	0.585	0.039	1.035	0.430
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.002	0.002	0.066	0.798
In Exp Plots	1	0.105	0.105	2.799	0.098
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.071	0.071	1.889	0.173
In Exp Plots	1	0.004	0.004	0.099	0.754
Residual	77	2.902	0.038		

Biomass

Total Infauna

Source	df	SS	MS	F	P
Plot	5	0.156	0.031	8.461	0.000
Treatment	3	0.007	0.002	0.653	0.583
Treatment * Plot	15	0.038	0.003	0.686	0.790
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.003	0.003	0.812	0.3702
In Exp Plots	1	0.004	0.004	1.020	0.316
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.002	0.002	0.577	0.4497
In Exp Plots	1	0.000	0.000	0.128	0.721
Residual	77	0.284	0.004		

Annelids

Source	df	SS	MS	F	P
Plot	5	0.002	0.000	1.347	0.254
Treatment	3	0.004	0.001	4.082	0.010
Treatment * Plot	15	0.008	0.001	1.675	0.074
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.000	0.000	0.013	0.910
In Exp Plots	1	0.001	0.001	2.559	0.114
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.000	0.000	0.003	0.959
In Exp Plots	1	0.000	0.000	0.000	0.988
Residual	77	0.024	0.000		

Table 5 (continued)

Crustaceans

Source	df	SS	MS	F	P
Plot	5	0.004	0.001	1.990	0.090
Treatment	3	0.003	0.001	2.216	0.093
Treatment * Plot	15	0.008	0.001	1.256	0.251
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.000	0.000	0.446	0.506
In Exp Plots	1	0.002	0.002	5.569	0.021
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.000	0.000	0.002	0.966
In Exp Plots	1	0.000	0.000	0.106	0.746
Residual	77	0.031	0.000		

Molluscs

Source	df	SS	MS	F	P
Plot	5	0.109	0.022	5.969	0.000
Treatment	3	0.007	0.002	0.617	0.606
Treatment * Plot	15	0.039	0.003	0.718	0.760
Contrast of Shrimp cage vs Control cage					
In Control Plots	1	0.002	0.002	0.552	0.460
In Exp Plots	1	0.000	0.000	0.004	0.948
Contrast of Crab cage vs Control cage					
In Control Plots	1	0.002	0.002	0.648	0.423
In Exp Plots	1	0.002	0.002	0.469	0.496
Residual	77	0.280	0.004		

Table 6. Summary of experimental effects for the caging studies in Galveston Bay. The direction of Plot effects (Experimental versus Control Plots) and Predation effects (Control Cage versus Predator Cage) was determined from ANOVAs and associated contrasts. Brown shrimp were predators in the spring, and white shrimp and blue crabs were predators in the fall.

	Spring		Fall		
	Plot Exp vs Cont	Predation CC vs Shrimp	Plot Exp vs Cont	Predation CC vs Shrimp	Predation CC vs Crab
Total Infauna Abundance	=	=	=	=	=
Total Infauna Biomass	=	=	>	=	=
Annelid Abundance	<	=	<	=	=
Annelid Biomass	=	=	=	=	=
Annelid Size	>	=	>		
Available Polychaetes	=	=	>	=	=
Polychaete Diversity	<	=	=	=	=
Mediomastus spp.	<	=	<	=	=
Streblospio benedicti	<	=			
Glycinde solitaria			<	=	=
Paraprionospio pinnata			<	=	=
Crustacean Abundance	=	=	=	=	=
Crustacean Biomass	>	=	>	=	=
Crustacean Size	>				
Amphipod Abundance	>	>	=	=	=
Decapod Abundance	=	=	>	=	=
Mollusc Abundance	>	>	>	>	=
Mollusc Biomass	>	=	>	=	=
Mulinia lateralis	>	=	>	=	=
Rhyncocoela Abun.			<	=	=

Table 7. Significant interactions in the analyses of experimental results that suggest predation effects differed at control and experimental plots. The mean values shown are based on log-transformed densities from control cages and predator cages. Predators were brown shrimp in the spring and white shrimp in the fall.

Mollusc Abundance (Interaction term was not significant but contrasts results varied)

Spring

	Control Cage	Shrimp Cage	Contrast P	Change	% Change
Control Plots	0.491	0.286	0.04	-0.205	-42%
Experimental Plots	0.803	0.644	0.53	-0.159	-20%

Fall

	Control Cage	Shrimp Cage	Contrast P	Change	% Change
Control Plots	0.744	0.470	0.003	-0.227	-36%
Experimental Plots	0.998	0.986	0.119	-0.012	-1%

Amphipod Abundance (Interaction P = 0.018)

Fall

	Control Cage	Shrimp Cage	Contrast P	Change	% Change
Control Plots	0.324	0.196	0.061	-0.128	-39%
Experimental Plots	0.150	0.402	0.025	+0.252	+168%

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